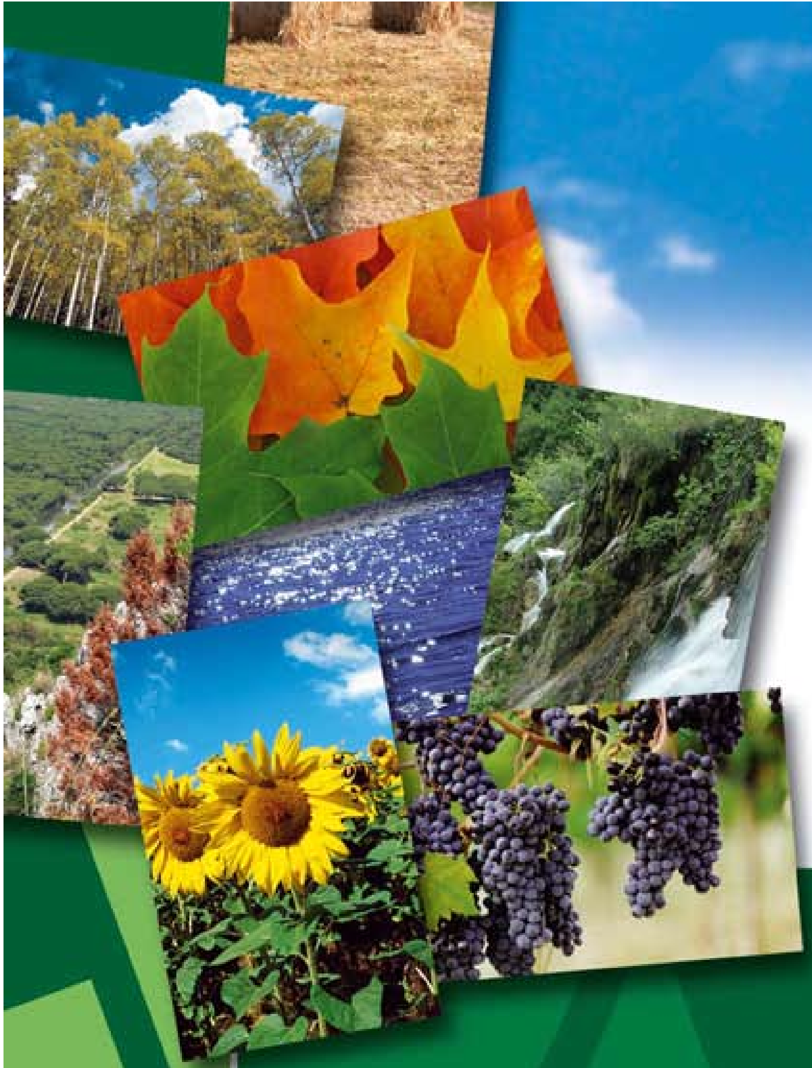

pro aere

agricultural projects for renewable energy in europe

THE PRODUCTION OF RENEWABLE ENERGY IN RURAL AREAS

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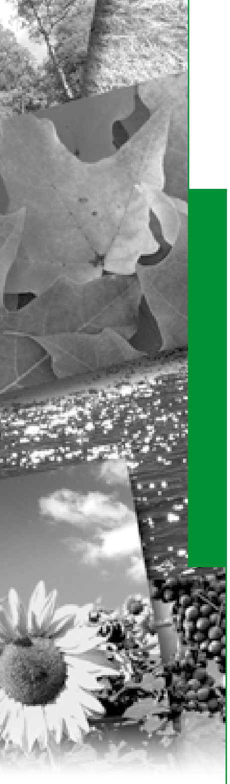


INTRODUCTION

Introduction

At present, the energy issue is a central topic in the debates for the future of our planet. The concern for the prospects of fuel depletion is combined with the concern for the climate change and its consequences. Among the solutions, submitted by the scientific community and the international institutions to these problems of global character, two strategies were outlined: the energy saving and the renewable energy sources.

The first condition for the success of these strategies is the promotion of a new, widely spread culture in relation to the energy, which, based on developed new professional skills in this area, to be capable of launching methods for production and sustainable energy use.

We are often witnesses of signs of awareness and sensibility to this subject, which, however, does not find any specific expression due to the lack of the respective knowledge, methods, plans to implement practically the good intentions. The purpose of the PRO AERE Manual, which is an attempt to highlight the subject for the renewable energy sources and, in particular, the agroenergies, is to spread knowledge and skills, referring both to the possible conditions for promotion of these energy sources and to the technical and economic aspects, connected with the various production cycles.

The Kyoto objectives

On 16 February 2005, eight years after its approval, the Kyoto Protocol entered into force, obliging 160 countries from all continents to undertake measures for reduction of the air-polluting emissions and to save the planet from the devastating climate changes.

The objectives set out by the Protocol, binding the signatory nations after ratification are, as follows:

- By the year 2012 an average reduction of the greenhouse gas emissions with 5% from the 1990 emissions levels;
- Commitment within the EU boundaries to make double the share of renewable energy sources from the present 6% to 12% by the year 2012.

Within the frames of the Protocol, similar objectives have been assigned to the signatory nations in compliance with the tendencies for energy consumption: thus, for the European Union, involving 15 states, the commitment for greenhouse gas emission reduction has been specified to 8%. The table below presents the emission levels, referring to the period 1990 – 2002 and the objective of each country's reduction by the year 2012:

Sources: EC, EEA, Eurostat

STATE	% EMISSIONS 2002/1990.	KYOTO OBJECTIVE	STATE	% EMISSIONS 2002/1990.	KYOTO OBJECTIVE
AUSTRIA	+8,5	-13	ITALY	+9	-6,5
BELGIUM	+2,1	-7,5	LUXEMBURG	-15,1	-28
DENMARK	-9,1	-21	NETHERLANDS	+0,6	-6
FINLAND	+6,8	0	PORTUGAL	+41	+27
FRANCE	-1,9	0	SPAIN	+39,4	+15
GERMANY	-18,9	-21	SWEDEN	-3,7	+4
GREECE	+26,5	+25	UNITED KINGDOM	-14,9	-12,5
IRELAND	+28,9	+13	TOTAL EU-15	-2,9	-8

Sources: EC, EEA, Eurostat

The outlined actions are, in fact, far from the actually necessary ones, yet their implementation is difficult with a view to the ongoing growth of the energy needs and the development processes, covering new areas on the planet, for example – China. It is sufficient to remind that the emission level, registered in Italy in 2004 instead of decreasing has increased with about 13% as compared to the 1990 level.

The European Union strategies

The European Union played a key role in the process, finalized in 1997 with the adoption of the Kyoto Protocol. What is more, even before the Protocol entered into force, the EU approved the Kyoto objectives (Decision of the European Council No.2002/358/CE, dated 25 April 2002).

The EU Directives in this area outlined the following objectives:

- The energy efficiency to be enhanced with about 1% annually;
- 12% of the necessary overall energy to be ensured until 2012 by renewable energy sources;
- 22% of the necessary electric energy to be ensured until 2012 by renewable energy sources;
- 2% and 5,75% of the necessary fuels to be ensured by biofuels until 2005 and 2012, respectively.

The Basic EU statutory instruments in this area are:

- Directive 2001/77/CE on the promotion of electricity production from renewable energy sources
- Directive 2002/91/CE on the energy performance of buildings
- Directive 2003/30/CE on the promotion of the use of biofuels
- Directive 2004/8/CE on the promotion of cogeneration

In regards to the renewable energy sources, EU has specified its development policy even before Kyoto in two major instruments, approved by the European Commission:

The Green paper, presented on 20 November 1996, outlining the European strategies for promotion of renewable energy sources. Except specifying the objectives, adopted by the subsequent Directives, it also examines the advantages of this option:

- environmental maintenance
- security of energy supply
- employment and sustainable development

The handicaps for promotion of the renewable energy sources involve the insufficient knowledge of the governing authorities as well as the technological and organizational problems in the separate production cycles.

The strategies to be implemented are also mentioned, focusing especially on two opportunities:

- regional policy, favouring the promotion of these types of energies, especially in the peripheral areas and the rural regions;
- coherent agricultural policy with a view to sustainable production and promotion of renewable energies

The White paper, presented in 1997, highlights the actions for implementation of the directions in the Green paper and outlines the following objectives in quantitative aspect:

- installation of one million solar photovoltaic systems;
- installation of wind power facilities for electric power supply of 10.000 megawatts;
- installation of biomass facilities for thermal power supply of 10.000 megawatts;
- implementation of 100 experimental projects for municipalities, towns, cities and districts, based on the integrated utilization of renewable sources

On 16 February 2001 the Action Plan was updated and the following suggestions were made:

- fostering the activities for promotion of energy production from biomass
- construction of small-scale hydro power facilities

The plan envisages both actions in support of investments in this area as well as promotion and information dissemination activities, mostly through the ALTENER Program.

Directive 2001/77/EC – "Green electric energy"

The approval and ratification of the Directive by the European Parliament and by the Council on 27 September 2001 is a major step. In contrast to the Green and White papers, containing fundamental aspects and directions, not binding the member-states, the Directive has legal force and imposes clear obligations on the EU countries.

In addition, the Directive includes methods for monitoring and urgent intervention in regards to the countries, not achieving their objectives. Finally, within the framework of the policy for energy market liberalization, a system would be applied in order to guarantee the origin of energy from renewable energy sources, along with specifying the type of source, the date and place of energy production.

The Action Plan for biomass

The last act of the European Union for promotion of energy production from biomass is the Action plan in regards to biomass, ratified by the European Commission on 7 December 2005. The instrument, which is an updated version of the previous instruments in this area, contains some important new elements:

1) The plan sets before the member-states the objectives of doubled energy production from biomass as compared to the current level. Actually, the Plan envisages the equivalent of 69 million tons of petrol (Tep) in 2003 to reach 150 million Tep by the year 2010;

2) The Plan clearly indicates the necessity of stimulating actions, directed towards biomass utilization in all areas of energy consumption: transport, electricity, heating.

3) The Plan refers to the subject of sustainable energy production from biomass, providing, though in most general aspect, for the preparation of legislation to regulate the ratio between imported materials and materials of local origin.

In conclusion, regulatory law such as norms and standards will soon be issued, which will be mandatory for the signatory states in relation to the share of biofuels to be utilized.

The European Program "Intelligent Energy for

Europe"

The program, incorporating previous programs of the European Union, provides for 4 types of activities in the period 2003- 2006, at the total amount of 200 million Euros within the framework of the Community:

- SAVE – improvement of the energy efficiency in construction and industry;
- ALTENER – promotion of renewable energy
- STEER – diversification of fuels by using renewable sources
- COOPENER – promotion of renewable sources and energy efficiency in the developing countries

The activities eligible for funding are:

- Creating structures and normative instruments, inclusive financial, for development of the local energy systems;
- Setting up systems for market certification and control, orientated to appropriate measures for sustainable development and sustainable energy supply;
- Development of information and training structures;
- Actions to monitor the undertaken measures and evaluate the projects' impact

The Reform of the European agrarian policy

The revision of the Community's agrarian policy, approved at the end of 2003, entering into force this year will change basically the conditions for agricultural subsidies.

- Setting aside the appropriations for farm cultures: the subsidy will not be calculated any more on the basis of the planted cultures, it will be determined by a complex mechanism, covering both the areas and the subsidies obtained in previous years (rights); therefore, the appropriations will not be connected with the use of terrains;
- increase of the funds, allocated for the rural development programs; this measure will result in allocation of larger amounts for the local development programs.
- compliance or, cross compliance: the subsidies to the income will depend on the observance of a series of norms and standards of the European Union, regarding environment;

In regards to the agroenergies, the Reform envisages an additional appropriation of 45 Euros per hectare for dedicated-energy crops.

The renewable energy sources as a new opportunity for rural development

Biological cycles and production of renewable sources
Models of energy self-supply of agricultural farms
The agroenergy company as an energy supplier
Agroenergies and models of local development
Energies from agriculture and for agriculture

The renewable energy sources and agriculture

When we speak about the renewable energy sources, we often forget or underestimate the substantial role of agriculture and the rural areas.

If we take into account only the sources with direct agricultural or forest origin - "the green energies", we can say that today they represent 50% of all renewable sources, utilized in Europe.

Besides, the agricultural areas are a natural place for potential development of the indirect agricultural energy sources, such as the wind and the sun.

We have good reasons to affirm that the rural areas submit too many opportunities for promotion of agroenergies and, of renewable sources as a whole.

- The mandatory objectives imposed by the Kyoto Protocol and the European Union oblige the member-states to double the share of their renewable sources;
- In regards to the biofuels, the commitment for 5,75% increase, imposed by Directive 2003/30/CE, requires Italy to achieve a 1000% increase of the current utilization levels;
- For some energy sources, such as hydro power, a major increase cannot be expected as a result of the already achieved implementation level as well as of the unsatisfactory policy in social and environmental aspect for the large water basins and the huge hydro electric systems;
- It is also unlikely to anticipate a major enhancement in the use of the geothermal sources.
- The technologies for utilization - even in small scale, of sources with agricultural and forest origin, for example – the wood biomass, were stimulated vigorously in the last years, making the use of similar resources very competitive;
- The European normative framework and its application at national and regional level avails new income opportunities for the agroenergy businesses.
- The resources, which we called "energies for agriculture", such as the sun and the wind, can submit soon, along with the liberalization of the energy market, interesting income opportunities for the agricultural farms.

A new model of energy production

The prospects for energy saving and promotion of new energy sources are connected with economic models, focused on the sustainable local development. This requires an explicit choice of strategies, targeted towards general energy saving and a wide-scale use of renewable sources by means of small and medium capacity installations, utilizing the energy sources on spot. This will reduce to the minimum the negative environmental effect and will foster both the economics and the environment of these territories. Therefore, a new model of energy production should comply with the following objectives:

Economic sustainability: the prospects for dedicated-energy agricultural and forest production are connected with the economic benefit of this activity for the business: i.e. with the added value which remains for the entrepreneur as a result of the energy transformation of the agricultural product.

In a production requiring industrial processing of agricultural product with/without huge expenses for transportation of the product to the processing facilities, the economic profit for the agricultural enterprise will be considerably lower. Therefore, the promotion of local production chains for direct utilization of agricultural and forest product is a solution, viable and economically feasible for the agricultural businesses. The following results will be achieved in this way:

- promotion of new agricultural and forest production regions and markets;
- lowered energy consumption of the businesses;
- territory valuation

Environmental sustainability: As a result of the energy transformation of the agricultural and forest biomass, a neutral balance of the carbon dioxide will be achieved, i.e. the quantity of released CO2 during burning will be equal to the quantity absorbed in the biological cycle. Whether the consequences of the biomass utilization would be favourable, however, will depend on the utilization conditions. For example, the biomass processing in the large electric-energy production facilities is connected with the following negative effects:

- low efficiency of energy conversion with considerable heat dissipation;
- high energy consumption for fuel transportation to the station;
- negative effect on the territory environment

Therefore, even in regards to the natural habitat, optimum results from the utilization of renewable sources can be achieved by short production chains.

Local development consistency: in the last years, the rural areas did a lot for the revival of the local businesses and tourism, creating a model of local development, perfectly incorporating the energy production from renewable sources. For this purpose measures should be undertaken for:

- Stimulation of large-scale construction of small installations;
- Promotion of agreements for production chains;
- Promotion of information and educational activities.

In conclusion, we can say that the promotion of renewable energy sources as part of the local development policy requires a vigorous financial support and, mostly - explicit norms and standards, outlined political targets and complex constructive methods. In our opinion, the following factors are of key importance:

- Undertaking measures, coordinated with the production sectors and the competent institutions (in the field of agriculture, environment, production operations, territorial arrangement, transport);
- Attracting the local authorities and the economic major circles.

Organizational models and entrepreneur activity for agroenergy production

Another aspect deserving attention refers to the possible organizational models of energy chains, their effect in the conditions of the new opportunities for development of agricultural farms as well as their role in the separate models.

For this purpose we'll outline three basic models, affirmed in the last years:

1) The model of energy production of closed-loop type, i.e. for satisfying the needs of the family / the farm
2) The model of selling waste materials for energy production
3) The model of energy sale

In the first organizational model, the agricultural company produces itself the necessary energy and consumes it entirely. The thermal energy, required for heating of residential and company premises can be produced, for example, by small boilers using waste wood, fragmented wood or pellets or, by solar panels. The need of electricity can be satisfied by photovoltaic roofs or wind-power mini installations. In this case, the entrepreneur will achieve considerable energy economy since he uses products or sub-products from the farm or natural energy sources. Obviously, careful evaluation should be made of the installation costs, of the achieved economy and of the respective terms for investment pay-back.

The model of selling waste material for energy production is an entrepreneur activity, whose characterisitics differ, depending on the organization type of the production chain. As we have already mentioned, in the case of industrial energy production in large power stations which, in most cases are far away from the facilities for waste material production, the agricultural companies will be seriously harmed since the cost for processing and transportation of the waste materials will considerably decrease the added value for the producer.

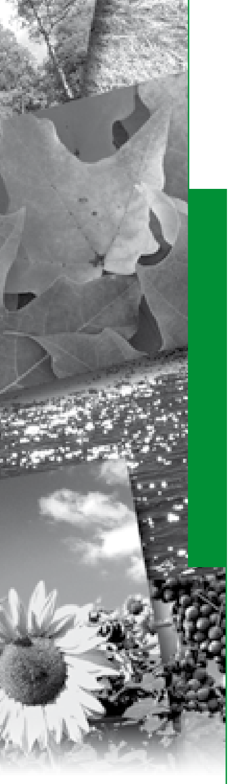
Different is the situation with the small and medium-scale installations, implemented on local level and characterized by a short production chain, in which the producers also participate. This both decreases the negative environmental effect and ensures larger income for the farmers. This is the case, for example, with the heating networks, fired with fragmented wood, used for heating of small municipalities, public structures or residential areas. In this case the local origin of the waste material and the direct negotiation of the price between the participants in the production chain ensures a higher added value for the producer. In the last years, predominantly in some countries, the model of selling energy from the agricultural farms was set up. In this case we have more or less complex types of organization. The simplest case, which we'll call "warm up your neighbour" is the case with businesses, constructing small heating networks which both satisfy the needs of the business and deliver heat to the closest neighbours as well. In other cases the entrepreneurs create small closed-loop production chains, thus providing their clients with an installation, waste material and installation maintenance. Another type of energy sale is the supply of electric energy for the grid, produced by photovoltaic panels or by wind power installations. State-of-the-art experience has been accumulated (we are going to give an example in the next paragraph) of associations or agricultural cooperatives, devoted to energy production. These are really existing agroenergy businesses where the farmers both supply waste material for the business and possess a share in its profit – either directly or, through energy recovery (for example, biofuels).

In conclusion, we can say that the energy production from renewable sources is a good opportunity for the agricultural companies. The profitability and gain of this activity depend on how successfully the farm manages the separate phases of the production chain.

In the next chapters we'll examine the main cycles of energy production from renewable sources, referring to agriculture and the rural areas, and we'll try to describe their characteristics, applications, and opportunities. In order to characterize better the various sources and their relation with agriculture and the rural areas, we'll divide them into two large groups:

ENERGIES FROM AGRICULTURE: they originate directly from the energy processing of farm and forest products and sub-products; they might become a new opportunity for the agricultural companies in the context of fostering the multi-functional role of the sector and within the framework of a vision for sustainable development.

ENERGIES FOR AGRICULTURE: energy sources, such as the sun, the wind and the hydro energy; they might be used in the rural areas and, as we'll see, they represent a potential for income, although they don't originate directly from the agricultural and forest operations.



ENERGY FROM WOOD

Introduction

Wood energy is a term which denotes both wood for fuel and cycle of energy production using natural wood resources. Wood as any other plant biomass is the product of photosynthesis, i.e., production of carbohydrates from solar energy. This is the third most widely used source of energy in the world after petroleum and coal. It is generally accepted that its reasonable use contributes to the maintenance of the biochemical equilibrium on the planet (renewable carbon does not contribute to the greenhouse effect, sulphur content is insignificant, etc.). The interest in wood energy has been encouraging the development of new technologies integrating automation of fuel loading and combustion management for several decades. These new technologies are characterized by their very good parameters both for the energy industry and environment. The sources of this energy are very important and are obtained from:

- forest (stumps, residue, small dry branches ...)
- agriculture (waste products from pruning of trees, young offshoots from clearing, waste from farm products...)
- human activities (wood for recycling...)
- industrial activities (chips, shreddings, shavings, pellets, briquettes ...)

The role of wood energy in the European scenario of renewable sources

Europe has many forests, starting from the subarctic regions down to the Mediterranean Sea. Forest areas cover approximately one third of the territory of Europe (115 million hectares of forests). Some European states are very rich in forests, for example, over 45 % of the territories of Austria, Sweden and Finland are occupied by forests.

Technologies for production of energy from wood have been developing in Europe more and more. Today there is a clear will to use this energy source – the first renewable fuel which is available in the greater part of the member states of the European Union.

A resource still widely available

On the whole, the area in Europe covered by forests is growing. In most of the states this process is still going on, mainly through afforestation of abandoned farmland. The yield of timber is much lower than the annual growth. In the average, only 50 % of the annual growth of forests in Europe is used for production. The situation is different in each member country, but on the whole the yield potential, without taking into account the renewed resources, is still great. A considerable part of this potential can be used for the production of energy from wood. With the accession of the new 10 member states to the European Union this resource is growing much more.

Today wood is the main source of renewable energy for the European Union: it is used to produce more than 50 % of the primary energy from renewable energy sources in the EU. According to Eurobserver (see Table 1) the primary energy production from wood for the 25 EU member states was 55.4 million of tones of oil or petroleum equivalent (mtoe) for 2004. This production includes waste wood, ethyl alcohol and solid waste from farm crops. This production has been intended mainly for heating needs, but the use of wood and its by-products for energy production is growing quickly (+23.2% compared to 2003, or 35 TWh for 2004). The share of energy from wood in the production of primary energy in the 25 EU member states corresponds to 3.2 % versus 3 % for 2003.

Table 1: Consumption of primary energy produced from wood in the 25 member states of EC in 2004 (in million toe) (Source: EUROOBVERSER 2005)

(in mtoe)	2003	2004 (forecasts)	Growth, %
France	9,002	9,180	2
Sweden	7,927	8,260	4,2
Finland	6,903	7,232	4,8
Germany	5,191	6,263	20,7
Spain	4,062	4,107	1,1
Poland	3,921	3,927	0,2
Austria	3,222	3,499	8,6
Portugal	2,652	2,666	0,5
Latvia	1,240	1,300	4,8
United Kingdom	1,084	1,231	13,6
Denmark	1,071	1,113	3,9
Italy	1,015	1,083	6,7
Czech Republic	0,895	1,007	12,5
Greece	0,909	0,927	1,9
Hungary	0,777	0,805	3,6
Netherlands	0,561	0,720	28,2
Lithuania	0,672	0,697	3,7
Slovenia	0,422	0,422	0,0
Belgium	0,346	0,382	10,4
Slovakia	0,300	0,303	1,1
Estonia	0,150	0,150	0,0
Ireland	0,145	0,144	-0,6
Luxembourg	0,015	0,015	0,0
Cyprus	0,006	0,006	0,0
Malta	0,000	0,000	
Total 25/EC	52,488	55,439	5,6

An accessible energy source

The biggest wood energy producers are France followed by Sweden, Finland and Germany. More than 60 % of the European wood energy production is attributed to these four states. In many European states the wood energy occupies an important place in the primary energy production. For example, Finland (57 %), Portugal (47 %), Austria (32 %), and Sweden (27.5 %).

Last researches on energy prices in France, Italy and many other states confirmed that wood is the cheapest fuel in the market, especially in the domestic sector. It would have been better, if this applied to all types of renewable energy. But thought this is not so, it will not delay developments in the renewable energy industry. As about the investment in the production, it is not higher than for other energies, even on the contrary. And so, the European public will, in line with its international engagements for environmental protection worldwide, as well as the will of consumers who have been informed about the advantages from wood energy, unlock and speed up things.

Prospects for development and strategies for the wood energy production cycle

The European Union ranks wood energy at one of the front places as a future energy source for the increase of its energy independence and has included it in its long-term plans. The EU target for 2010 is to produce 12 % of its gross energy for internal use from renewable energy sources, and for the wood the target is 100 % increase of the production at 45 mtoe. This corresponds to a market of over 30 million households which use wood for heating by means of individual, collective and city heating systems.

Presently, efforts are focused mainly on the development of residential steam systems and communal heating grids in compliance with the adopted national or regional plans as is now in Austria, Denmark, Finland, Sweden, and also in France, Italy and Germany. As for the production of wood energy, a lot of efforts have to be made in many states so that wood could find its place under the new conditions of a free electric energy market.

And finally, as for the individual domestic heating sector, efforts for its development are still insignificant, even though more than 85 % of the EU households are using individual systems. The already existing technologies offered to private persons should lead even to more considerable results than expected in the industrial and collective sectors. To activate this process, however, many more people will be needed than now. This, of course, is an invitation for joining hundreds of enterprises, associations and organizations which are now working across all Europe for the promotion and implementation of the wood energy. Tens of thousands of new jobs are waiting to be created!

Strategies for production of heat from wood

Supply of fuel

- Demonstration of innovative equipment in the systems for processing of forest wastes.
- Demonstration of machines for harvesting, transportation and storage of wood.
- Systems which can increase the development of the logistics of supply of biofuels.

Technology of combustion

- Demonstration of technological innovations contributing to the yield increase, reduction of investment and harmful emissions.
- Demonstration of innovative technologies widening up the range of fuels used.

Domestic heating

- Demonstration of a biomass heat system outside the zone of conventional use, with harvesting and production systems.
- Development of equipment which will contribute to lowering of prices and harmful emissions, enhancement of reliability of heating components, improvement of harvesting, production, storage and supply of fuel.

Integration measures

- Identifying and calculation of advantages from wood energy for the environment.
- Projects outlining the access to an integrated system allowing for enhancement of reliability.
- Harmonization of European standards for wood fuel, harmful emissions, equipment, safety

Market activities

- A range of innovative marketing activities for distribution of the information (leaflets, CD-ROM, videos, database, symposiums, workshops, exhibitions, practical training).

Strategies for production of electric energy from wood

Supply of fuel

- Demonstration of innovative equipment in the systems for processing of forest wastes.
- Demonstration of machines for harvesting, transportation and storage of wood.
- Research and development of alternative energy crops for the adapted areas.
- Prolongation of programmes of melioration of energy crops to raise yield.
- Development of systems intended to speed up the development of the biomass fuel supply sector.

Combustion

- Demonstration of innovative technologies for increase of yield, reduction of investment, widening the range of fuels used and lowering of harmful emissions.
- Demonstration of small systems for wood energy production

Gasification / Pyrolysis

- Demonstration of a range of technologies for gasification and pyrolysis suitable for many different regions in the EU.
- Research, applied development and demonstration of small systems for wood energy production with the use of advanced equipment.
- Demonstration of pyrolysis systems.

Integration measures

- Identifying and calculation of advantages from wood energy for the environment
- Projects outlining the access to an integrated system allowing enhancement of reliability
- Harmonization of European standards for wood fuel, harmful emissions, equipment, safety

Market activities

- A range of innovative marketing activities for distribution of the information (leaflets, CD-ROM, videos, database, symposiums, workshops, exhibitions, practical training).

Wood energy production cycle and rural development

The use of wood for energy applications has been attracting progressively more political and business interests as it has numerous advantages on local level:

- Prompt economic benefit and creation of jobs for persons of various qualifications by virtue of the various woks required by the production cycle for achieving the target - utilization of by-products from exploitation of forests and their processing for energy needs.
- Creation of revenues and further development of current

workplaces in the energy sector: the wood energy creates 4 to 5 times more jobs than the competitive natural gas, fuel oil, coal and electric energy. 2,000 m3 wood for energy would directly create full-time qualified jobs for a forestry entrepreneur, carrier, equipment manufacturer, design engineer, traders, mechanical fitters, even computer programmers.
- Use of competitive fuel by consumers.
- Enhancement of the total confidence in the economy as a result of the increased energy independence and limitation of the risks from uncontrollable price rises due to international crises.
- Participation in protection of local environment.
- Extension of the time to depletion of reserves through the use of renewable energy.
- Contribution to maintenance of forests and improvement of landscape, sanitation of forests and firefighting.
- Financing of forestry activities (thinning, slashing and pruning) which are carried out from time to time, and reinvestment in the forest – a source of future renewable materials and fuel.

Wood energy production cycle and environmental impacts

Long-term development, very favourable world situation for wood energy

Energy is present in all fields of human activity. Fossil energy sources are of finite quantity and are a cause of serious pollution and wars. Developing states with a limited access to the exceptionally expensive fossils energy sources are in the most unfavourable position and at the same time they have to cope with the increase of population and improvement of living conditions. As for the developed states, they are suffering the results of a very expensive energy dependence and serious environmental problems. Most of the states have already started a process for solving this situation, which includes measures for environmental protection, development of the economy, and in other words – they have prepared plans for a long-term development. The energy from wood is the most widely used renewable energy in the world and is an important part of the long-term plan of development.

Wood as renewable fuel

Wood is an energy source which regenerates through photosynthesis. Its reasonable utilization will nor harm what will be left to future generations. It allows to save the fossil energy sources (petroleum, natural gas, coal, uranium) which are of finite quantities and of non-uniform distribution. The time for regeneration of wood is much shorter compared to the other energy sources.

Energy	Period of regeneration	Estimated reserves
Wood	from 15 to 200 years	renewable
Coal	from 250 to 300 million years	500 years
Petroleum	from 100 to 450 million years	50 years

Table 2: Comparison of regeneration periods of wood, coal and petroleum (Source: EUROFOR, INESTENE)

The main advantage of wood energy is, however, that it does not contribute to the greenhouse effect. The quantity of CO2 which is released in combustion of wood is comparable to the quantity produced during its natural decomposition – this quantity of CO2 corresponds to the quantity absorbed through photosynthesis in the growth process. In this way, equilibrium is maintained and therefore the CO2 balance is equal on both sides.

Impacts on soils and biological diversity

Forest exploitation is not necessarily a synonym of deforestation. If it is not intensive or illegal, as in Europe, it will have no negative impact on quality of soil or water conditions, or still less on biological diversity. The best approach, and the one requiring the least investment at the same time, is an exploitation based on the natural regeneration of forests in which nature is following its own course and man is harvesting what nature has produced. That is why, it is necessary to conduct a reasonable exploitation with a careful monitoring of forest conditions. In many states the exploitation of forests for production of wood for energy meets this requirement. In other states, however, it will be necessary to impose both legal measures and educate the population.

Harmful emissions

To determine the main sources of pollution it will be good to consider the various factors of harmful emissions. Comparison between all harmful emissions shows the following trends:
- Wood produces about 20 times less net harmful emissions of CO2 than natural gas and 30 times less than fuel oil.
- Wood produces about 20 times more emissions in the form of particulate matter than the natural gas and 10 times more than the fuel oil. And in fact, nitrogen oxide emissions are two times higher than in fuel oil and 4 times higher than in natural gas.
- Sulphur dioxide (SO2) emissions are 3 times higher in fuel oil compared to wood and natural gas.
- The total quantity of hydrocarbons released by wood in the atmosphere is the least.

Table 3: Factors of harmful emissions in fuel oil, natural gas, wood chips (beech) and wood logs (beech) in kg of TJ useful energy (= mg/MJ useful energy) according to study No 315 of Heizenergie aus Heizöl, Erdgas oder Holz (Federal Agency of Environment and Forests)

Pollut-ant	Fuel oil 100 kW	A	B	Natural gas <100 kW	A	B	Wood chips 50 kW	A	B	Wood logs 100 kW	A	B
CH4	112	1	99	412	<1	100	31	77	23	92	93	7
HDM	223	1	99	60	5	95	53	68	32	171	83	17
CO	31	17	83	53	58	42	1510	98	2	1110	95	5
CO2	91100	86	14	66400	87	13	3460	0*	100	3010	0*	100
SO2	126	53	47	33	2	98	40	80	21	39	82	18
NOx	92	29	71	51	40	60	199	80	20	168	80	20
Particu-late	9,9	1	99	5,8	2	98	117	93	7	126	95	5

HDM : Hydrocarbons different from methane
A = Factors of emissions related only to direct combustion in percent; B = Factors of emissions related to yield, transportation and infrastructure, in per cent. *The CO2 consumption is shown only for **B**, as the 150 000 mg CO2/MJ useful energy from wood logs and chips are considered as renewable and regenerating in the growth of forests.

Use and removal of ash

Ash from natural wood can be used as fertilizer in agriculture if complying with certain criteria. Requirements which it must meet and quantities that will be used are determined in conjunction with local agricultural authorities. Ash from fully natural wood can be used in small quantities as a fertilizer in vegetable gardens. An area of 100 m2 can get up to 30 litre per year which corresponds to 5 m3 of wood. Higher quantities will be an unnecessary burden to soil and water. Excess quantities are disposed of together with household wastes or are spread over other sites with the owner's approval. Ash from the processed wood shall in no case be used as a fertilizer and it shall be disposed of in accordance with the current legislation. Normally, the law prohibits the use of fertilizers for forests. Wood ash is considered as fertilizer. Organic and mineral fertilizers can be used only in nursery gardens and also in planting or setting out. If the forest legal provisions allow it, return of ash to the forest will close the cycle of wood energy. The main ingredients of ash are calcium, silica, potash and magnesium. These elements are mainly in the form of oxides. The following elements are of importance to make ash more valuable: calcium (20 % - 25 % by weight), potash (2 % -10 %) and phosphorus (0.5 % – 1.5 %). The greater the portion of wood processed (rejected wood, paper, packaging and wastes) is, the higher the concentration of heavy metals (zinc and lead) will be in ash.

Table 4 : Average composition of ash from burning of different firewood (Source: Hasler 1994, Ruckenbauer 1995, Noger

Element Unit Wood Chips Bark Rejected wood P G/ kg 9,4 10,9 7,4 4,1 Ca G/ kg 320 250 300 220 Mg G/ kg 27 34 39 17 k G/ kg 66 59 42 19 Pb Mg/ kg 18 36 25 2100 Cd Mg/ kg 2,2 3,9 17 20 Cr Mg/ kg 35 140 130 470 Co Mg/ kg 11 17 24 20 Cu Mg/ kg 210 180 90 1200 Mo Mg/ kg 4,5 3,4 4,8 7 Ni Mg/ kg 45 72 94 180 Hg Mg/ kg < 0,5 1 Zn Mg/ kg 380 1430 620 6900

P : Phosphorus, Ca : Calcium, Mg : Magnesium, K : Potassium, Pb : Lead ,Cd : Cadmium, Cr : Chrome, Co : Cobalt, Cu : Copper, Mo : Molybdenum, Ni : Nickel, Hg : Mercury, Zn : Zinc

Ash for fertilizer shall not exceed the following recommended levels (in mg/kg dry matter).

Table 5: Recommended concentration of heavy metals (Source: ITEBE, report 2004)

Lead	Cadmium	Chrome	Cobalt	Copper	Molybdenum	Nickel	Mercury	Zinc
100	3	100	12	150	6	60	1	600

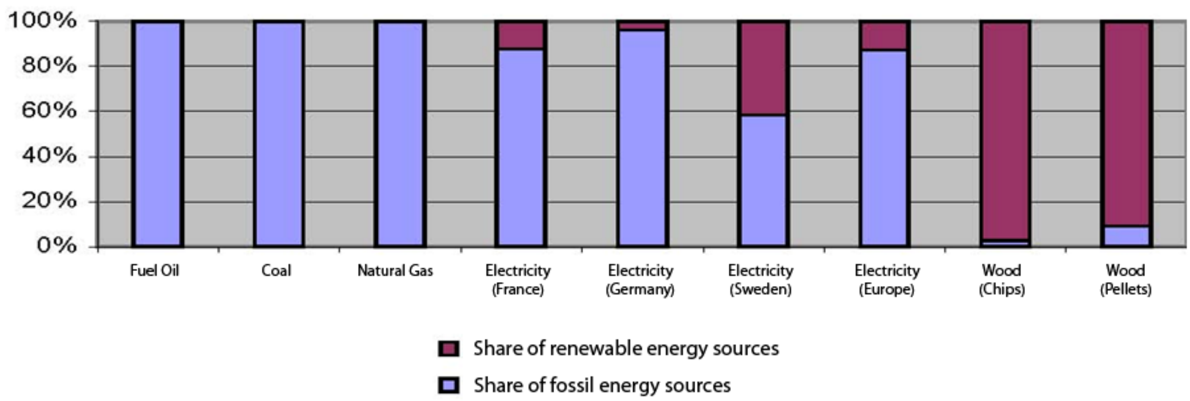
Wood energy – a positive impact on forests and landscape

The use of wood energy contributes to maintenance of forests and landscape. The energy evaluation of agricultural and forest wastes allows for improvement of the sanitation condition of forests. Collection of waste products protects forests against growth and propagation of parasites and diseases. This facilitates replanting and encourages such forestry operations as thinning and slashing. This encouragement of forestry activities contributes to enhancement of quality of future forests and increase of forest resources. The use of wood energy also allows for evaluation of by-products and wastes from the woodworking industry. A large quantity of by-products and wastes is produced from wood processing and these can be used as fuel.

Low consumption of energy

To produce a certain quantity of energy in the form of heat, a boiler will need to be charged with a certain quantity of energy in the form of wood. The relation between the quantity of energy consumed in the form of fuel and energy produced in the form of heat is the efficiency of the boiler. Presently, this efficiency is about 80 % in boilers run on chips and 85 % for the boilers run on pellets and the expectations are for a further increase. Still, some energy is spent for fuel production and its transportation up to the boiler – mainly in the form of fuel for the wood cutting machines and log lorries. The share of each phase of the fuel production is shown in the diagram below. As seen, it is cheaper to transport the wood chips within a distance of up to 100 km or a little more. The balance of the wood chips is almost similar to this of natural gas and fuel oil. The wood chip production chain has the lowest consumption of energy at only 4 kWh non-renewable energy for the production of chips which supply 100 kWh heat. The share of the renewable energy in the balance of the wood application is very important since energy from fossil sources (i.e. non- renewable) is used only in the wood production chain. In the application of chips or pellets (from dried renewable wood) only 3 % and 9 % non- renewable energy are consumed respectively. Then, in the combustion process is used only wood, that is, non- renewable energy.

Table 6: Share of the renewable energy in the production of heat from various fuels (Sources: Valeur environnementale de l'énergie, 2000; Assessment of bioenergy system, 1999; Wood sustain, 2001; IEA, 1998)



Aspects involved

Productions of wood chips

The production of chips from wood is a rather simple forestry or agricultural activity. It is a range of some classical works: cutting, loading, transportation. But still, two of the operations are special: splitting and drying. In fact, the difficulties in the production of quality chips at competitive prices come from the planning of the operations and the logistics of the delivery.

There is a wide range of alternatives for wood splitting both in terms of organization and productivity. There is a good choice of high quality machinery from different manufacturers available in the market. Splitting is by a rotary machine with blades. Wood chips are not produced with hammer mills – normal operation of heating systems requires that the composition of the chips will be very uniform by size.

There are five types of splitting machines: small splitters transported by farm tractors: tractor-attached splitters; mobile or self-propelled splitters; heavy-duty stationary splitters mounted on a lorry or semi-trailer; and stationary splitters.

Production of wood logs

In many European states the wood in the form of wood logs is the most widespread wood fuel for heat. For example, the annual consumption of firewood in France is above 50 million m3. But for all that, the firewood market is affected by many factors: illegal markets, competitive energies, high price of production in some cases, no uniform quality of fuel, inconvenience of use.

So, there is a prompt necessity to improve quality of products and minimize production costs in order to develop this market. The harvesting and preparation of the firewood has to be improved. These have been done mostly with conventional means until most recently. Today they are being modernized through extensive mechanization. There is a trend to move from conventional wood production methods to production on permanent sites.

The logistics of firewood production is often not covered by process specifications since firewood is still being considered as only a secondary product from the production of wood for industrial applications. In the last ten years the new equipment intended for the whole process of firewood production (for example, wood felling machines, combined felling-cutting machines, measuring machine for wood volume, etc.) made it possible to improve and provide specifications as a whole for the logistics of firewood production and preparation for immediate use.

Wood energy production cycle

Waste products from forestry management operations

Operations related to forest management, that is, thinning and pruning, which are carried out with the purpose to produce high quality wood for industrial applications, as well as forest harvesting are a source of waste products such as branches and tree-tops. Too much of these often undersized materials can find no application. France considers producing at least two million m3 of these economic products, if the use of boilers fired on wood continues to rise. This will encourage the performance of many and various activities and will be very profitable for forest owners.

Waste wood from the woodworking industry

Wood felling for the woodworking industry is a source of very important residual products which can create value as a source of energy. The branches of each tree represent 15 % - 30 % of the whole tree and these materials are not suitable for sawmill processing. Of course, part of these branches are used as firewood or raw material for the paper mills or chipboard mills, but still no full use is made of these materials. At that, a large part of the waste wood is neither suitable for firewood nor further processing and so pieces of small diameter (below 10 cm) are very often left in the forest. The left over of these waste products have many negative implications:

- creation of conditions for starting of forest fires and propagation of parasites
- filling up of areas and making further forest operations difficult
- deterioration of forest appearance with consequent damage to the tourist business
- valuable energy sources that nowadays can already be put to some good use are being wasted
- and it is also a labour loss for the forest workers who spend part of their work time in cutting and burning of useless wastes

Treetops, branches and leaves

The treetop is the topmost part of a tree which is above the primary crown (branches, ramifications, leaves…). The term describes ramifications and the top part of the trunk which is not included in the bole. In colloquial language we speak of tops. These parts are normally of small diameter and are heavily ramified. Their utilization takes much time and it is very expensive in view of quantity and commercial value.

Treetops and branches are mainly used as firewood when developed more or less. Otherwise, but most often, treetops are collected and burned on site. It can be noted that the quantity of the produced treetops is equal to this of timber and that 50 % of the left over after cutting are treetops. These figures, of course, vary depending on the particular conditions at the clearing site.

It is considered that 25 % of the mass of the tops in young coniferous trees and 10 % in old trees are leaves. The proportions in deciduous trees are 15% and 5%, respectively.
The available quantities of treetops, branches and leaves are huge and methods for complete utilization of trees would make them highly valuable.

Waste products from maintenance of hedgerows and afforested areas outside forests

Chipping of branches

Development of green areas and most of all maintenance of hedgerows by farmers or road maintenance companies are also a source of left over for production of wood chips. This involves pruning of roadside trees, maintenance of parks and gardens, hedgerows, pastures, roadsides. These products are often burned or broken up and are left on site. Their exact quantity can be determined after detailed studies.

Shaping of green areas is also a source of left over for production of wood energy. This involves pruning of roadside trees, maintenance of parks and gardens, hedgerows, pastures... In general, maintenance of hedgerows leads to the harvesting of various products of highly varying quantities for wood energy production. In the average, 5 to 10 tonnes per 1 km hedgerow is a good basis for production of energy from wood.

Small trees and offshoots from forestry operations

Waste products from thinning

These are products from periodic cutting (3 - 4 times per generation) the objective of which is to reduce the thickness of a forest by removal of these trees which are hindering or excessive. The useful quantity, together of branches above 8 cm, produced from first thinning is considerable and is suitable mainly for heat fuel. Next thinnings can eventually produce sawlogs for timber production and also waste products (treetops, branches, etc.) that can be used as energy fuel. Thinnings for production of wood blocks (too small products) which are considered as being of insignificant quantity for energy fuel can also be of interest. In this way, quantities from 50 to 100 tonnes per hectare can be obtained.

Forest felling

Felling sites are woodland areas which are afforested and are felled or cut down in short intervals. They have been the conventional source of production of heat wood for long time. Felling sites have a short production cycle – fast growing species are being planted, young trees are cut down within a short time of growth, stumps are removed and the site is afforested again. Abandoned felling sites turn into a natural mixed forest of offshoots and high trees of different age.

Felling sites are a resource which is very suitable for production of energy wood, the more so as left over from trunks have to be split – something which is never done in the conventional timber production.

Plantations intended for chip production

Many of the felling site, parks and other plantations are not suitable for timber production or pulpwood for chipboards either because of the tree species or high exploitation expenses. In many cases, necessary measures that would allow timber production have not be taken in due time. The chip production for fuel applications offers a quality solution for the utilization and proper management of such woodlands.

A heap of wood for chopping

When a balance sheet is drawn up the figures show that the problem is not with the resources which are diverse and abundant. Every year in France are grown trees in quantities above 25 million m3 which are not being utilized and therefore bring no revenues. This is a fine opportunity to develop wood energy production without interfering with other wood applications! All these resources, if a more suitable application is not found, can be processed into wood chips for heat. Only a small part of treetops and branches are used as heat wood after processing. Trees, left after removing particular trees during the process of thinning, are intended for subsequent high quality timber production for industrial purposes. Wood produced from thinning operations normally is of too small sizes to find an application other than splitting into chips for chipboards or wood fuel.

Characteristics and productivity

Felling, shedding and topping

Felling or cutting down, shedding or removing of limbs, and topping or removal of tops to cut logs of optimal length are the primary operations. The tree is felled at the stump and then shed and topped into different products: sawlogs, branches, treetops. These operations take place normally on site from November to March in the period of "juice descent" for a quick wood drying as a result of the natural scarcity of juice. At a large woodland where trees are of a bigger sizes these primary operations can be mechanized on a suitable landing of not so rugged surface. When mechanization is combined with suitable conditions such as sufficiently flat terrain, trees in straight rows and of considerable volume, then felling expenses will be considerably reduced. The cutting methods can be divided in three groups:

Manual method: this is the most widespread method. A power saw is used for felling, shedding and topping. This method is especially suitable for trees of large diameter, curved trees and when the terrain does not provide easy access to heavy-duty machines.

Left: Oak felling by power saw
Right: A crawler-mounted feller Tigercat

Semi-mechanized method: felling is by a power saw, haulage to the roadside or a landing by a skidder with winch or log grips and shedding/topping is with a machine. This method is suitable for felling sites with straight trees.

Mechanized method: suitable for terrains with a small slope where a harvester can be easily used. The machine cuts down trees at the stump and then sheds and tops them into lengths from 2 to 4 m. The harvester is a heavy vehicle useful for a production at an extensive rate. It can produce from 50 to 100 m3 per day in a trouble-free work process.

Haulage

Haulage is the shifting of processed product to a roadside landing by means of a skidder with winch or log grips, agricultural tractor with trailer or manually. Horses can be also used in places not easily accessible, normally within distances of 100 m or for transportation of wood products of smaller sizes (first thinning of small trees and offshoots). The bigger the trees, the cheaper will be the haulage process. Mechanized haulage can be performed with various machines:

- Agricultural tractor-mounted winch
- Tractor with a crane fitted with log grips and a trailer
- Grapple skidder
- Tractor with loading crane for bundled logs
- Forwarder with a loading crane – this is a heavy-duty machine on a 4, 6 or 8 wheel carriage and of carrying capacity from 8 to 15 tonnes, of production output from 50 to 100 m3 per hour depending on the model, or even still more, if bundles are being hauled. This type of machine is recommended for logs of length 2, 4 or 6 m.
- Lifting machine: with four-drive wheels and one or two winches, used normally for lifting of large trees with tops and limbs intact and transportation to a roadside or lifting of bundles of logs.

An agricultural tractor-mounted winch for haulage applications

Other non-mechanized methods are used for haulage in sloped areas:

- A steel rope suspended between two trees allows for sliding felled trees or logs outside the slope without damage to the forest.
- Transportation chutes allow easy removal of logs of diameter less than 35 mm out of the sloped zonee

Haulage by a skidder with winch

Haulage by a forwarder with a loading crane

Production of wood chips

Small tractor-attached chippers

These small-sized machines which are farm tractor-mounted are most widespread. They can be manually supplied with wood material or work in combination with a crane and are suitable mainly for chipping of wood for agricultural needs, clearing of the surroundings and are normally operated by forest owners, farmers and communal authorities. Chipping takes place on a site next to the stored waste wood, at roadsides and hedgerows, even at a sloped terrain in the forest or felling sites at the time of finishing works. The chipper can discharge the chips into a trailer or lorry, or even directly at the storage place. The diameter of the wood processed at such chippers should not exceed 30 cm which means that in practice they are most suitable for material of diameter from 3 to 20 cm and length up to 2 m. The output varies in the range of 1 to 3 CMC per hour in manual feeding or from 3 to 10 CMC per hour with crane feeding (CMC= cubic meter of produced chips).

A small tractor-attached chipper

Medium-size wheel carriage mounted chippers

These are intended for some more professionally specific operations as compared to the above. There are two types: driven by their own engine or by the engine of the haulage lorry or tractor.

These machines require from 70 to 160 HP and are suitable for chipping of wood material of diameter from 10 to 35 cm. These machines are used in accessible places since it is difficult to transport them over rugged terrain. Feeding can be by hand or crane and the output is normally in the range of 3 to 20 CMC per hour, but can be even higher in bigger models.

A wheel carriage mounted chipper

Self-propelled chippers

The self-propelled chippers are mounted on a 4, 6 or 8 wheel carriage intended for rugged terrain. They have a loading crane and a container of volume of about 15 m3. The chipper itself is of a medium-size capacity (normally 30 cm diameter) and is suitable for harvesting and processing of branches left on site.

These are machines for professional use and annual production in the range of 30,000 CMC. Their output is 20 CMC per hour in the average as they are also harvesting the wood material to be processed. On bigger felling sites this output can be increased with the use of another machine for harvesting and discharging wood material into the chipper container. The self-propelled machines can be used after the primary processing operations, but their weight and sizes do not permit their use on unstable or very sloped terrains.

A self-propelled chipper

Large stationary chippers

These are the biggest models of chippers suitable for operation on site a storage facility or at the roadside for processing of large quantities of wood (500 to 1000 m3). They are lorry-mounted or hauled on trailer and have their own engine of 350 to 600 HP which allows them to process wood of diameter up to 40-60 cm and even higher. Their capacity is in the range of 40 to 100 CMC per hour. In view of this output, one good logistics can make it possible to achieve continuous discharging of the ready chips to the chip delivery lorries without any downtime both for chipper and lorries.

A self-propelled chipper

Stationary chippers for trees, logs or other wood of poor quality

When boilers which have to be supplied with wood fuel are located in very large rooms, it may be possible to install a chipping platform that will provide part of the fuel. Thus it becomes possible to buy whole trees, logs or boards which are of poor quality not suitable for other applications.

These machines which are normally of high output can also process baled branches. This method has been also used for the production of energy from small branches and treetops, complementing another two already operating systems:

- self-propelled chippers for production on site of the felling process. However, this method cannot ensure high production throughout the whole period since it may be possible that the felling site is covered with snow in the heating season, or the site is not accessible, or the moisture content of wood is too high;
- haulage of the bulk wood to the roadside where left for drying and chipping by stationary machines during the heating season. Because of the above stated causes this system can also be affected by the adverse atmospheric conditions;

In the baling process residue wood material that cannot be transported by some other method are pressed in bundles. They are transported with log lorries, put in storage and then chipped at the consumption site at a profitable cost at the suitable time.

A bale chipper

A heap of bales

Production of wood logs for fuel
Splitting

Splitting is an operation by which the round wood material is split into 2 to 16 pieces. The aim is to reduce the diameter of parts to assist drying and burning for the heat process. The difficulties and risks of the splitting operation, and also production costs can be minimized through mechanization.

Hydraulic splitters

The hydraulic splitters consist of a base on which the round wood material is put and a hydraulic jack carrying a blade or wedge. The wood is split by the blade or wedge under the compression force of the jack. These machines are powered either by the engine of the tractor or by their own petrol engine or electric motor. They can process from 5 to 30 tons wood of length of about 1 m and achieve an output of 2-3 m3 per hour.

Photo 14: A horizontal splitter (Kretzer)

Photo 15: A vertical splitter with winch (Rabaud)

Photo 16: A splitter with crane (POSCH)-Screw splitter

Screw splitters

This type of machine splits the wood by means of a screw driven by the tractor engine. They are designed for domestic applications. DANGER: these machines are dangerous and we would never recommend to you to use such machine. It is very easy to get your clothes caught up and die in terrible conditions.

Splitting hooks

The splitting hook makes the job easier by minimizing efforts for processing of wood. It splits the wood in 4, 6 or 8 parts and can be installed at any crane or tractor with a grapple. It is used only for splitting of large wood logs. This is a machine complementing the work of other splitters.

Combined cutters/splitters

Now increasingly more manufactures are selling combined splitters that can both cut and split wood for fuel. These machines are optimizing the production of wood fuel by saving intermediate handling from one to another machine. They can cut and split wood logs of diameter 30-40 cm. Large wood logs can be conveyed, cut and split on these more or less mechanized platforms (conveyor, chain, grapple…). These machines can process 5 to 15 m3 per hour depending on the machine model. Selection criteria in such combined machine will be depending on the size of wood to be cut and split (diameter and length), required production rate, stationary or mobile application, availability of machine operators, existing facilities, and most of all, financial potential.

A cutter/splitter (BGU Machinen)

A cutter/splitter (Palax)

A horizontal cutter/splitter (Japa)

A cutter/splitter (Binderberger)

Cutters/splitters on platform

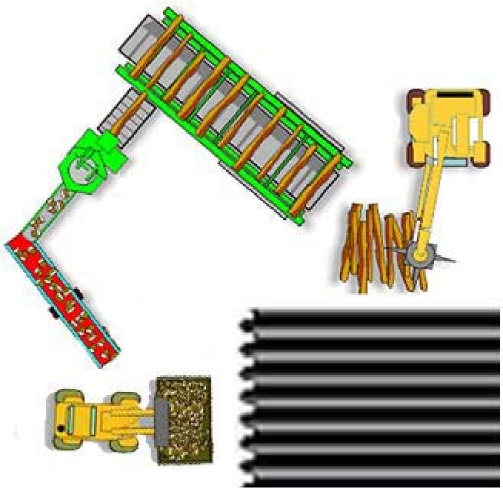


Diagram 1: Platform-mounted cutter/splitter

Splitting and cutting of the wood logs are carried out at a platform for production of wood fuel. Performance of splitting in one place allows faster removal of cut down trees from the clearing site. This type of exploitation makes it possible, above all, to organize a better grading for the wood fuel and optimize the output at larger quantities. This system can process from 90 to 120 m3 per day.

In general, a platform for production of wood for fuel would include:

- Receiving and storing place for the primary material delivered as unprocessed logs in 1 m, 2m, 4m or more.
- Place for automatic cutting with a power saw in the required length and splitting in 2, 4, 6 or more pieces depending on diameter of logs and type of splitter.
- Storing and drying place.

A platform (Ktretzer)

A platform (Pinosa)

Cutting

When cutting has not been done at the time of splitting, the two halves of the split log will be cut. It is possible to organize the work in various ways.

In the store, at a platform or at the customer's place

One possibility is to have always dry logs of length 1 m in stock and to cut them at the customer's place. This method has three disadvantages. First, the wood material is dried in length 1 m which requires more time than if the length is less. Second, consumption of energy in cutting of dry wood is higher since dry wood is more rigid. Third, transfer of the cutting process to the customer's place takes much time. Instead, cutting can take place on the felling site or at a platform. This allows to cut the logs immediately after splitting when still wet and to store them under a shelter.

Heat wood log cutter

In bundles or in bulk

If the 1 m logs are not bundled they will be cut one by one with a portable power saw. Stacking of logs in 1 m3 bundles will allow cutting of the whole bundle in smaller lengths with a portable power saw. There are also automatic machines with a large saw blade to cut the bundles. So, stacking of logs saves time.

Cutting a bundle on pallet

A Bundle cutter (Arci), in lengths of 50cm

Quality of energy from wood fuel

Composition of wood – that is CHO

The process of photosynthesis is described in brief in the following equation:

CO_2 + H_2O + minerals + solar energy = biomass + O_2

The main composition of completely dry wood by weight is in the average 49 % carbon (C), 45.3 % oxygen (O), 5.5 % hydrogen (H), 0.2% nitrogen (N). This composition determines the heat value and conditions at which combustion of wood has to take place.

Fuel efficiency is not determined only by the thermal characteristics of the organic matter components. Physical and chemical qualities of fuel also play an important role in the combustion process: moisture, granulometric composition, apparent volumetric weight, density, specific surface, ash quantity, composition and qualities of inorganic components (minerals, metals, halogens, alkaline metals).

The organic composition of wood includes mainly cellulose, lignin and mineral substances which will produce the ash.

Table 8: Proportion of wood components

Wood composition	%
Cellulose	from 40 to 50 %
Hemicellulose	from 10 to 30 %
Lignin	from 15 to 30 %
Organic matter and minerals	from 0.5 to 2 %

As about the water, there are two types contained in wood: water in the molecules of lignin which is chemically bound to wood, and capillary and absorbing water in the cell walls and pores of wood which is physically bound to it. This water can be removed by drying.

Table 9: Change of heat value depending on moisture (ITEBE)

Moisture per gross weight	LHV, kWh/tonne	Moisture per gross weight	LHV, kWh/tonne	Moisture per gross weight	LHV, kWh/tonne
8 %	4552	28 %	3432	48 %	2312
9 %	4496	29 %	3376	49 %	2256
10 %	4440	30 %	3320	50 %	2200
11 %	4384	31 %	3264	51 %	2144
12 %	4328	32 %	3208	52 %	2088
13 %	4272	33 %	3152	53 %	2032
14 %	4216	34 %	3096	54 %	1976
15 %	4160	35 %	3040	55 %	1920
16 %	4104	36 %	2984	56 %	1864
17 %	4048	37 %	2928	57 %	1808
18 %	3992	38 %	2872	58 %	1752
19 %	3936	39 %	2816	59 %	1696
20 %	3880	40 %	2760	60 %	1640
21 %	3824	41 %	2704	61 %	1584
22 %	3768	42 %	2648	62 %	1528
23 %	3712	43 %	2592	63 %	1472
24 %	3656	44 %	2536	64 %	1416
25 %	3600	45 %	2480	65 %	1360
26 %	3544	46 %	2424		
27 %	3488	47 %	2368		

Heat value

Change of heat value depending on moisture

Lower heat value (LHV) expressed in kWh/kg is the energy produced in the burning of a certain fuel taking into account the latent heat from steam production contained in the water steam produced. The volume weight and LHN are dependent on composition and moisture of wood. Heat value of wood is much variable depending on moisture. This is so because much of the energy released in the combustion of biomass is used for evaporation of water and this reduces the quantity of the energy produced. We can speak about upper heat value (UHV) only in the case of condensing steam boilers.

The lower heat value per gross weight of a wood fuel can be calculated according to the moisture and heat value of the dry wood from the following formula:

$$\mathbf{LHVo \times (100 - Mgw)}$$

$$\mathbf{LHV = - 006\ .0 \times Hgw\ 100}$$

where: LHV – lower heat value, kWh/kg ; Mgw – moisture per gross weight, % ; LHVo – lower heat value of dry (dehydrated) wood, kWh/kg

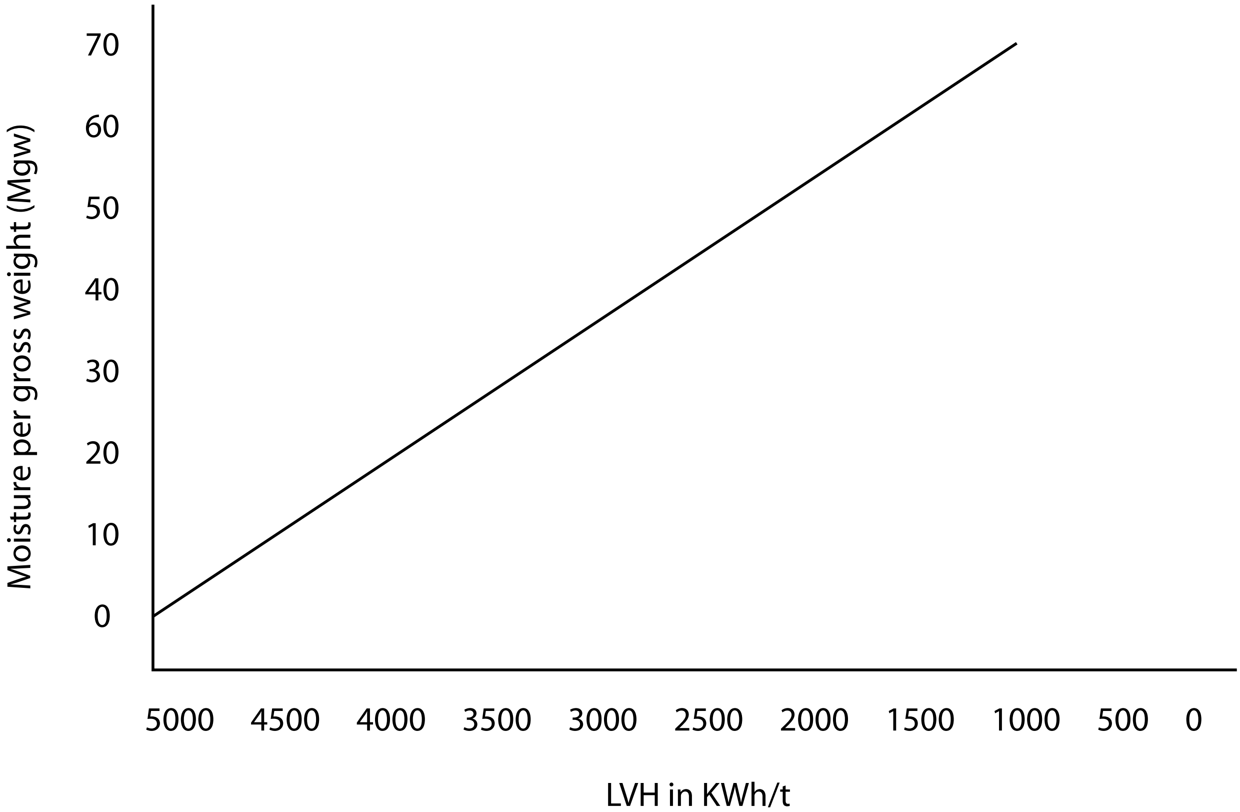


Table 10. Wood moisture as a function of LHV

LHV of some wood species as a function of moisture

Change of LHV depending of wood species is very small. What makes hardwood a better source of energy is not its heat value, but its volume weight. Coniferous species display a considerably higher heat value.

Table 11. Examples of some LHV (Source ITEBE)

		LHV as a function of moisture (kWh/tonne)													
	Moisture	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
	Wood species														
Hardwood	oak	4653	4377	4100	3824	3547	3271	2994	2718	2441	2165	1888	1612	1335	1059
	hornbeam	4530	4260	3990	3720	3450	3180	2910	2640	2370	2100	1830	1560	1290	1020
	beech	4596	4323	4049	3776	3502	3229	2955	2682	2408	2135	1861	1588	1314	1041
	ash tree	4663	4386	4109	3832	3555	3278	3001	2724	2447	2170	1893	1616	1339	1062
	elm	4815	4530	4245	3960	3675	3390	3105	2820	2535	2250	1965	1680	1395	1110
	acacia	4720	4440	4160	3880	3600	3320	3040	2760	2480	2200	1920	1640	1360	1080
	birch	4720	4440	4160	3880	3600	3320	3040	2760	2480	2200	1920	1640	1360	1080
	sweet chestnut	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140
	wild chestnut	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140
	fruit trees	4625	4350	4075	3800	3525	3250	2975	2700	2425	2150	1875	1600	1325	1050
	maple	5005	4710	4415	4120	3825	3530	3235	2940	2645	2350	2055	1760	1465	1170
Softwood	linden	4625	4350	4075	3800	3525	3250	2975	2700	2425	2150	1875	1600	1325	1050
	black alder	4625	4350	4075	3800	3525	3250	2975	2700	2425	2150	1875	1600	1325	1050
	poplar	4530	4260	3990	3720	3450	3180	2910	2640	2370	2100	1830	1560	1290	1020
	willow	4530	4260	3990	3720	3450	3180	2910	2640	2370	2100	1830	1560	1290	1020
	white pine	5005	4710	4415	4120	3825	3530	3235	2940	2645	2350	2055	1760	1465	1170
	sea pine	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140
	weymouth pine	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140
	silver fir	4815	4530	4245	3960	3675	3390	3105	2820	2535	2250	1965	1680	1395	1110
	European spruce	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140
	common larch	5005	4710	4415	4120	3825	3530	3235	2940	2645	2350	2055	1760	1465	1170
	black fir	4910	4620	4330	4040	3750	3460	3170	2880	2590	2300	2010	1720	1430	1140

Impact of wood species on heat value and volume weight

The actual volume weight shows the weight of a certain quantity of compact wood. It is measured in kg/m3. Volume weight and LHV are dependent on wood species and moisture. (Based on data from France).

Contrary to expectations, the LHV of a certain quantity of wood does not vary excessively as a function of moisture. Whatever the moisture is, dry matter content remains the same – the difference comes from the water which will evaporate. That is why, the differences will be considerable when calculations are made for tonnes of wood.

Table 12: Change of LHV per wood quantity depending on moisture (ITEBE)

Type of wood		Wood species	Heat value of dehydrated wood	Minimum volume weight	Maximum volume weight
			kWh/kg or MWh/t	kg/m3 compact	kg/m3 compact
Hardwood	Deciduous	common box		910	1160
		oak	4.9	550	900
		hornbeam	4.8	800	900
		beech	4.9	690	910
		ash tree	5	630	1000
		elm	5.1	600	850
		acacia	5	660	770
		birch		600	630
		sweet chestnut		550	740
		wild chestnut	5.2	540	540
		fruit trees	4.9	580	860
		maple	5.3	570	740
Softwood		linden		490	580
		alder	4.9	440	660
		poplar	4.8	400	700
		willow	4.8	380	520
	Coniferous	yew		670	900
		cedar		450	810
		white pine	5.3	480	890
		sea pine	5.2	520	770
		weymouth pine		320	490
		silver fir	5.1	380	650
		spruce	5.2	340	580
		common larch	5.3	450	670
		black fir	5.2	450	480

Quality of chips

The three main parameters by which wood chips for fuel can be specified are:

- granulometruc composition,
- moisture,
- heat value.

There are also some secondary parameters:

- quantity of ash,
- particulate matter content,
- presence of admixtures,
- presence of mildew.

Criteria that have to be taken into consideration:

Granulometric composition

It determines the technical solutions and size of the storage place, feeding of the boiler and combustion. It affects the increase of the volume and therefore the area occupied by it. Variation in quantity for one type of wood fuel can reach up to 30 % depending on whether chips are small or large. In fact, small dry chips are suitable for small automatic boilers used by an individual household or for small heat transfer grids. Chips of bigger granulometruc composition are suitable for industrial boiler systems or in general systems above 600 kW.

Moisture

This is the quantity of free water in the wood fuel. It can be calculated in percentage of moisture per gross weight (Mgw) and more rarely in percentage of moisture of dry weight (Mdw). The relations shown below are calculated from the following formula:

$$\text{Mdw} = \frac{100 \times \text{Mgw}}{100 - \text{Mgw}}$$

Heat value

The heat value of wood is the theoretical quantity of energy produced in the process of combustion. The value obtained for solid fuels is the LHV (lower heat value), that is, the quantity of released energy excluding the energy consumed for evaporation of the water originally contained in the wood (water in the form of evaporated steam). The heat value of wood is dependent on the moisture in the wood, but also on its composition (for example, quantity of carbon in wood). Moisture and heat value of dehydrated wood allows to calculate the actual heat value of the wood per gross weight from the following formula:

$$\text{LHVo} \times (100 - \text{Mgw})$$
$$\text{LHV} = - 006\ .0 \times \text{Mgw}100,$$

where:

LHV – lower heat value, kWh/kg
Mgw - moisture per gross weight, %
LHVo –lower heat value of dehydrated wood, kWh/kg

The energy value of wet wood chips varies in the range of 2200 to 2800 kWh per tonne at moisture from 40 to 50 %. The energy value of dry wood chips is in the range of 3300 to 3900 kWh per tonne at moisture from 20 to 30 %.

Ash quantity

Ash is the residue from burning of wood. It is composed of unburned particles and minerals: calcium, magnesium oxide, potash, silicon oxide, phosphorus acid and alkaline salts. Quantity of ash is highly variable depending on wood species and part of wood burned (trunk, bark, branches). This quantity can be also increased by the presence of contaminants such as soil and stones from processing operations.

Particulate matter content

Particulates are fine particles of size below 1 mm remaining from processing and transportation of the wood. In general, its content in chipped wood should not be higher than 5 % of the total weight of the wood. Wood quality should match the type of boiler where it will be burned. Normally, the smaller the boiler is the higher quality requirements for wood fuel are.

Foreign matter

The presence of any admixtures such as metals, stones, sand, soil, glass, plastics, etc. is not permitted since all these can lead to undesirable consequences.

Mildew

Mildews are an indication for decomposition of the wood. Presence of mildew means that the product will not meet customer's requirements, especially concerning heat value. In addition, some mildews are harmful for the lungs and should be generally avoided. In the event such material is to be processes, a protective mask should be used. When such material is delivered the customer should be informed about this matter and it will be good to take measurements of the LHV (Price: € 250).

Measurement methods

Measurement of moisture and of granulometric composition can be taken by the customer himself, but for the other measurements a laboratory should be contacted. Moisture measurements inside a drying chamber can be taken by any agricultural laboratory.

Measurement of moisture

The most accurate method is to take a sample from the material and leave it in a drying chamber at 104°C for stabilization of the weight (24 h at least). Other methods can be used, but they are not more reliable (measurement bucket, microwaves). Measurements can be taken either by the supplier or consumer – in fact, by the person requiring such information.

Granulometric composition and content of particulate matter: the only method is a screen of hole sizes determined by the customer – a size for the maximum granulometric composition and composition of particulate matter.

Properties of wood fuel

Knowledge of characteristics of wood fuel

- Wood species is an important characteristics which has to be taken into consideration
- Moisture is the factor which effects most the quality of combustion: to obtain efficient combustion it is necessary to use dry wood fuel of moisture below 25 % by gross weight,
- Shape and size of wood fuel: It is recommended to use wood of length and diameter suitable for the size or furnace or fireplace. That is why, wood logs are prepared in sizes of 50, 33 or 25 cm. Wood logs have to be split.
- Cubature of the wood fuel is factor which has to be accounted for when choosing the place of storage.

Effect of wood species

The harder the wood is, the higher the energy content will be. The wood species gives information about the energy content of the particular quantity of wood fuel. Wood is divided into hardwood and softwood. Hardwood (oak, hornbeam, beech, ash tree, acacia, etc.) is heavier and of higher energy content than the same quantity of softwood (alder, poplar, willow, linden and the coniferous).

Still, the heat value per unit weight varies little in different wood species. And what more, the coniferous varieties have even a slightly higher LHV (plus/minus about 5 %). This difference is not of sufficient importance to be taken into account and is generally neglected.

And so, the reason why the oak has a higher energy content than the spruce is not that it has a higher heat value (at the same moisture one kilogram of oak wood releases almost the same heat as one kilogram of spruce wood), but because it is more solid.

Energy content values depending on wood species and moisture

Notes

- Harwood such as oak, hornbeam, beech, or ash tree normally is considered as the best for wood fuel.
- Acacia, sweet chestnut and the coniferous are good as wood fuel, but produce much sparks.
- Softwood such as birch, poplar, and linden is very good as wood fuel by virtue of its flash point.
- Often design engineers recommend avoiding continuous use of coniferous wood fuel because of the risk of contaminating and blocking of the system with tar substances. Only heating systems with adequate controls, open fire facilities such as fireplaces and storage ovens, and these with an accumulator are suitable for trouble-free use of coniferous wood fuel.

Effect of size of wood fuel

The shorter and more split in small pieces the fuel wood is, the better it will burn. Different lengths of wood logs are possible depending on the type of the heating system: 1 m, 50 cm, 33 cm, 25 cm or shorter. The size of the wood fuel is dependent on the heating system:

Table 13 : Values of energy content depending on wood species and moisture (Source:ITEBE)

Wood Species	Total moisture	Average weight per cu.m. wood	Lower heat value	Energy content	equivalent fuel oil in litres
Deciduous (Hardwood)	20 % 30 %	530 kg/cu.m. 600 kg/ cu.m.	3.9 kWh/kg 3.3 kWh/kg	2070 kWh/ cu.m. 1980 kWh/ cu.m.	210 l/ cu.m. 200 l/ cu.m.
Deciduous (Softwood)	20 %	380 kg/ cu.m.	3.9 kWh/kg	1480 kWh/ cu.m	150 l/ cu.m
Coniferous	30 %	440 kg/ cu.m.	3.3 kWh/kg	1450 kWh/ cu.m.	145 l/ cu.m

Size of wood fuel	Application. Comments
1 metre	Only for an open-type fireplace or boilers with a large furnace. Boilers will need an accumulator.
50 cm or 33 cm	A size suitable for boilers with a small furnace and for closed-type fireplaces.
33 cm and 25 cm	A size suitable for stoves, cookers and cook and heat combined stoves
Twigs and cut offs	Only for boilers with a door – always with a feed chute

Size of wood fuel, both length and diameter, is an important factor for quality of combustion. It is always preferable to use short wood logs (25-33 cm), split in pieces of maximum diameter from 10 to 15 cm.

Calculation of volume of wood fuel

The volume of any quantity of wood fuel will be reduced at each cutting. The cubic metre or a stere is a widespread unit of measure from the metric system. One cubic metre is the quantity of wood stacked in a container with a cubic shape of 1 m wall. The use of other non-metric units is preferably to be avoided since these units are not the same in different regions. The table below gives the correspondence between 1 cubic metre of wood logs cut in lengths of 1 m, 50 cm and 33 cm. After splitting, for example, 1 m3 whole wood logs will make 1.5 m3 .

Table 14 : Examples of correspondence between one cubic metre of wood logs cut in lengths of 1m, 50 cm, 33 cm (ITEBE)

CONVER-SIONS Values in m3	Logs 1 m	Logs 50 cm	Logs 33 cm
Figures by CTBA, France	1	0.8	0.7
Figures for Germany	1	0.9	0.79

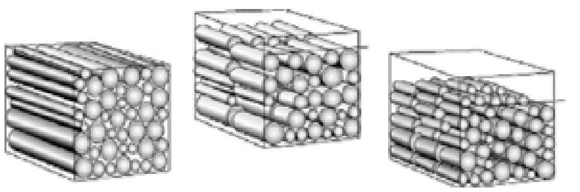


Diagram 2: Calculation of volume of wood fuel

One cubic metre of 1 m whole logs occupies obviously and according to definition a volume of 1 m3 (a). In France it will occupy not more than 0.8 m3 in the average after cutting the logs in length of 0.5 m (b) and not more than 0.7 m3 after cutting in length of 0.33 m (c).

The explanation of this phenomena is that arrangement is more compact when logs are shorter as the empty space will be less.

The cubic metres of wood fuel can be stacked also in the form of round bundles.

The use of the cubic metre was criticised because of the ambiguity it can cause since the weight of one cubic metre changes considerably depending on diameter, stacking and straightness of logs. In other states, as in Italy, wood fuel is measured according to the weight after checking the moisture as this measurement is considered to be more adequate.

The use of weight as a unit of measure has its advantages and disadvantages. Wet wood logs are much heavier and of less energy content, and so it is possible to be sold at a price above their worth. In return, if moisture is measured, the weight is a more accurate unit of measure as it gives more precise information about the energy content than the volume. The energy content of wood can vary depending on wood species and shape.

Effect of moisture on wood

The drier the wood fuel is, the higher its energy content will be. Moisture is the main criterion for quality of wood fuel (See above the chapter on drying process). The gross moisture of wood should not exceed 25 % during combustion. The heat value of wood is in inverse proportion to the water content. Heat value determines the rate and efficiency of combustion. If we try to burn a wet wood piece, it will ignite with difficulty and a great part of the energy from its combustion will be consumed for evaporation of the water and this will cause an important loss of certain efficiency. In addition, combustion will not reach the temperature necessary for decomposition of all molecules and will lead to air pollution (smoke), contamination of the combustion chamber (tars) and the flue stack (soot). For example, 1 kg wood of 50 % moisture will produce 2 kWh, while if the moisture is 20 % it will produce 4 kWh. In other words, when burning wood of moisture 50 % we will consume 2 times more wood fuel than in wood fuel of moisture 20 %. That is why, drying shall be so planned that the moisture content shall be about 20-25 % at the time of the sale.

Table 15 : Effect of moisture on heat value (Source: ITEBE)

Moisture of wood	Heat value
50 – 60 %	2.0 kWh/kg wood
25 – 35 %	3.4 kWh/kg wood
15 – 25 %	4.0 kWh/kg wood

Organization of production

Logistics of wood chip production

The diagrams below will give an illustration of the main types of the production organization. Not all possibilities for interruption of the operations would be discussed below as this subject was treated above and also because our intention is to make a simple presentation as brief as possible.

Chipping on the felling site

A self-propelled wood chipper in operation on the felling site

Advantages

No primary processing of raw material (time saving).
No transshipment required.

Disadvantages

Rugged relief and wet soil can hinder the application of this method; Considerable negative impacts for forest soils; Necessary use of three machines at a time; Loss of time, if the chipper is used to remove the chips out of the site; A risky decision, if the production flow is continuous; Low chipping output Ø<30 cm; Felling site is occupied for a long time.

Wood chip production with a self-propelled chipper on the site of felling	
Type of felling site	Clearcutting or first thinning Ø < 30 cm
Selective clearing	Manual or mechanized, and wood is arranged in rows to facilitate processing by the chipper machine
Haulage	Tractor and trailer for shifting to the chipper or only a self-propelled chipper
Transportation	Containers of 30 to 40 m3, with determination of the required number in advance
Economic aspects	10 €/CMC, wet chips, produced at sites with highly optimized production (Hedeselskabet, Denmark)

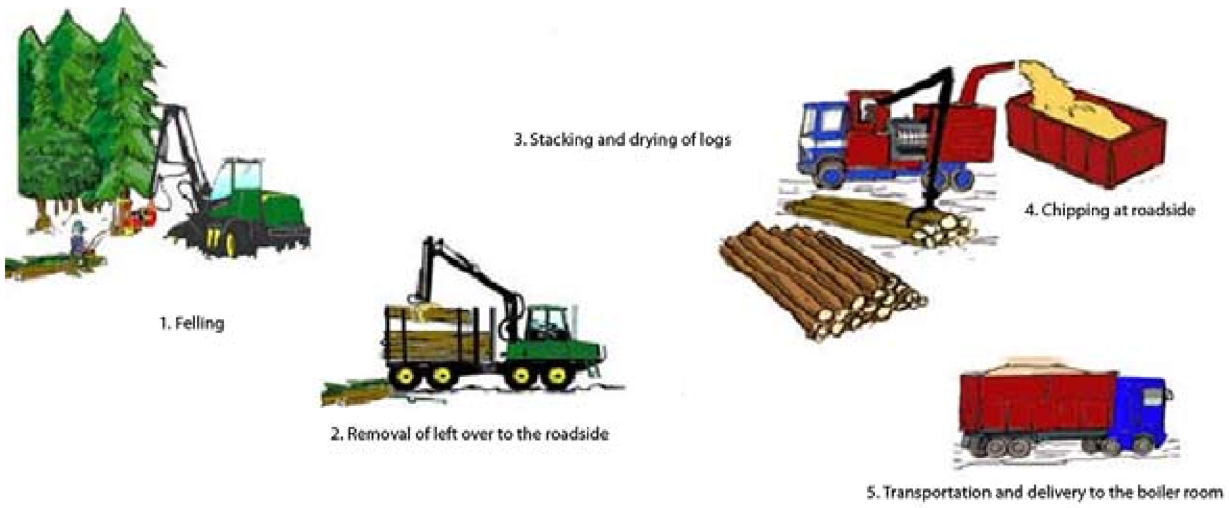
Diagram 3: Chipping on the felling site (Source: ITEBE)

Source of illustrations: TIMBERJACK – SYLVATEC, ITEBE

Chipping at the roadside

Left: A chipper at a forest roadside landing
Right: A chipper at a roadside

Diagram 4: Chipping of stacked wood at the roadside (ITEBE)



Source of illustrations: TIMBERJACK – ITEBE

Wood chip production at the roadside	
Choice of plantation	Any type of plantations Ø < 60 cm
Felling	Manual or mechanized
Haulage	Forwarders
Chipping	Chipper operating at the roadside. Opportunity for drying of logs before chipping
Transportation	Containers or trailers
Economic aspects	€ 12 - 15 /CMC (France)

Advantages
The easiest solution for the supply of medium-sized boiler rooms with wood fuel

Disadvantages
The chipper works 100 % of the time
Need of a large landing at the roadside
Machines work separately

Chipping at a mobile platform

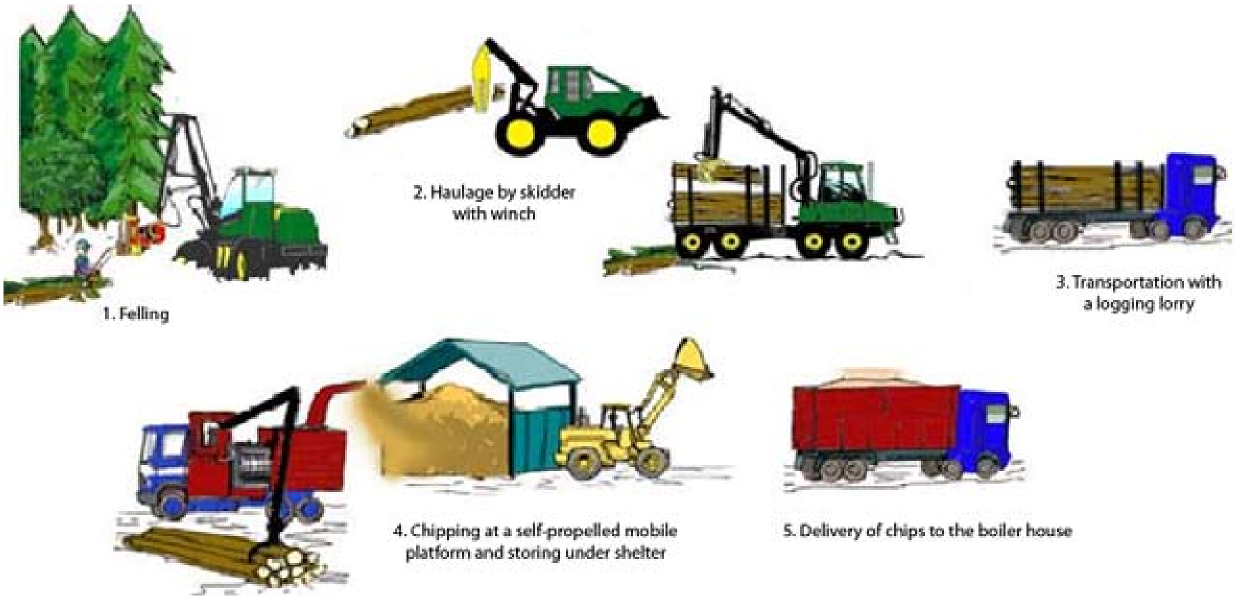


Diagram 5: Chipping at a mobile platform

Wood chip production at a mobile platform	
Choice of plantation	Whole trees Ø < 90 cm
Felling	Manual or mechanized, cutting of treetops in lengths from 6 to 15 m
Haulage	Skidder with winch
Transportation	Logs (treetops)
Chipping	Chipping at a mobile platform next to a shelter or directly on site of boiler house Opportunity to leave the logs for drying before chipping
Economic aspects	€10 - 12 /CMC

Advantages
Installing of a chipper of high output and cutting down of expenses
Separated operations and so no problems in the event of a breakdown
Use of conventional machines
High security for the supply

Disadvantages
Suitable only for big trees in big quantity, there -fore it is important to have a system of high output (> 5 MW)
No drying in the forest, direct delivery to a chipper mounted on a self-propelled platform

Subcase of baling

Logistics of wood fuel production

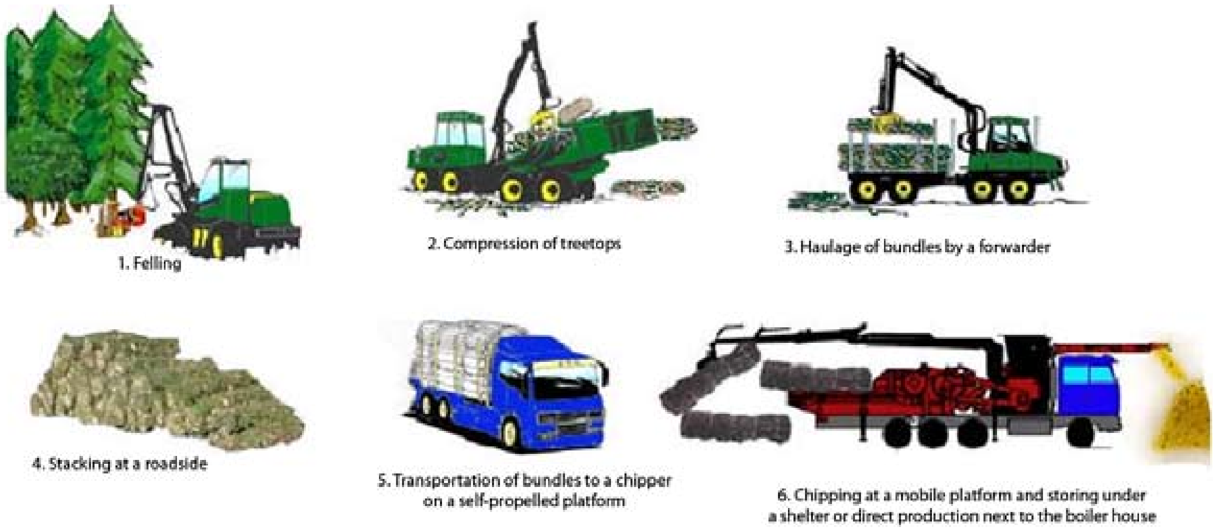


Diagram 6: Chipping at a mobile platform

Wood chip production from bundles at a self-propelled mobile platform	
Choice of plantation	Only small residue
Felling	Harvester for felling, topping and baling
Baling	From treetops and branches of length above 3 m. Bundles 0.6 to 0.8 m in diameter tied at each 40 cm. The bundling machine produces almost 20 - 30 bundles per hour, each of weight about 0.4 – 0.7 tonnes (Source: TIMBERJACK)
Haulage	By forwarders
Transportation	By conventional lorries
Economic aspects	An expensive solution due to extra personnel

Advantages
Installing a chipper with a high output – cutting down of expenses
Better utilization of small size wood
Opportunity to transport branches
Machines work separately

Disadvantages
Expensive solution
Suitable only for the small residue (diametre 3 cm
Suitable only for output systems

Conventional production of wood logs (Case 1)

The conventional wood log production is the most expensive process, if works are legally paid. It has the lowest efficiency and that is why the quantities produced are small.

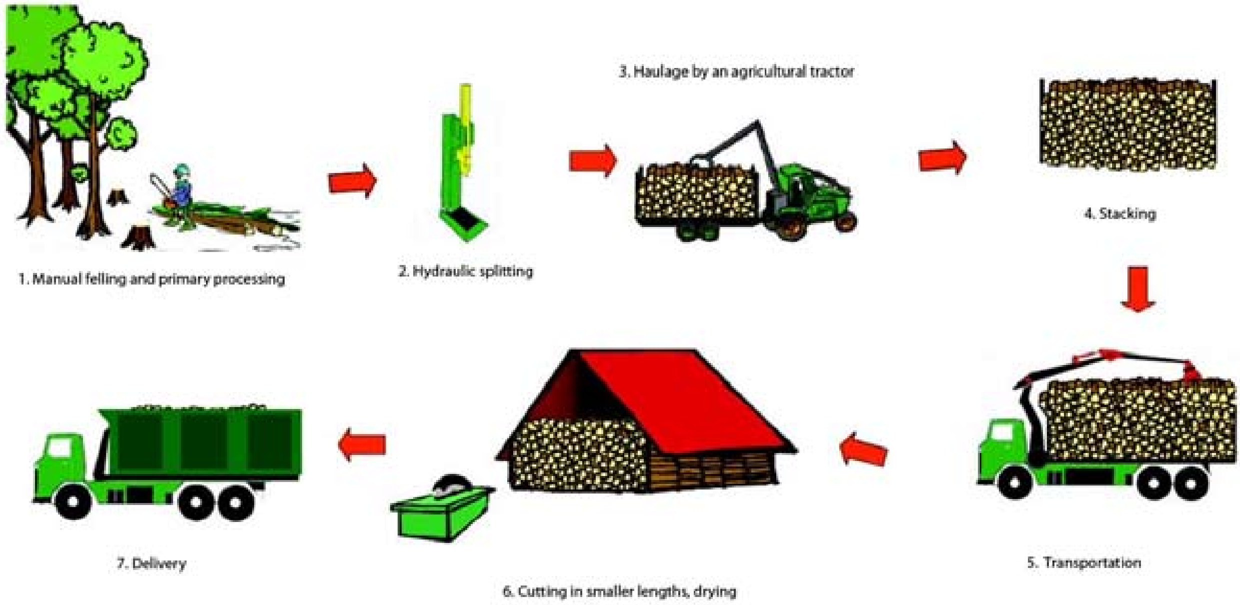


Diagram 7: Conventional production of wood logs (Case 1)

Phases	(Case 1)	Operations
1	Operations on felling site	Felling, shedding and topping with a power saw in length of 1 m
2		Splitting of 1 m logs, splitter being driven by a tractor engine
3		Haulage of logs by tractor and trailer with or without loading crane
4		Manual or crane-assisted stacking at the roadside (6 to 18 months), with or without cutting in advance.
5	Transportation	Delivery to the customer or transportation to a platform for cutting and/or drying before sale, either manual or mechanized
6	Cutting and/or drying platform	Cutting in lengths of 50, 33 or 25 cm at a cutting platform, if not done at the time of felling
		Drying under a shelter for sale of dry wood logs (6 months) or in the open (12 months)
7	Delivery of cut wood logs	Delivery in bulk or stacked on pallet (manually or mechanized) by lorry to the customer (consumer or trader)

Required equipment (Case 1):

- Cutters,
- Hydraulic splitters,
- Agricultural tractor,
- Forestry trailer,
- Eventually a loading crane with log grips or tractor and trailer
- Stationary or portable band or circular saw
- Agricultural lorry or forwarder for haulage
- Processing and storing site
- Eventually a building for drying and storing of dry wood logs for sale

Production of wood logs fastened with ribbon steel at 1 m (Case 1b)

Fastening of measured quantities of wood logs with ribbon steel to form a compact package is not an expensive operation that allows to achieve a considerable price reduction when small quantities are produced.

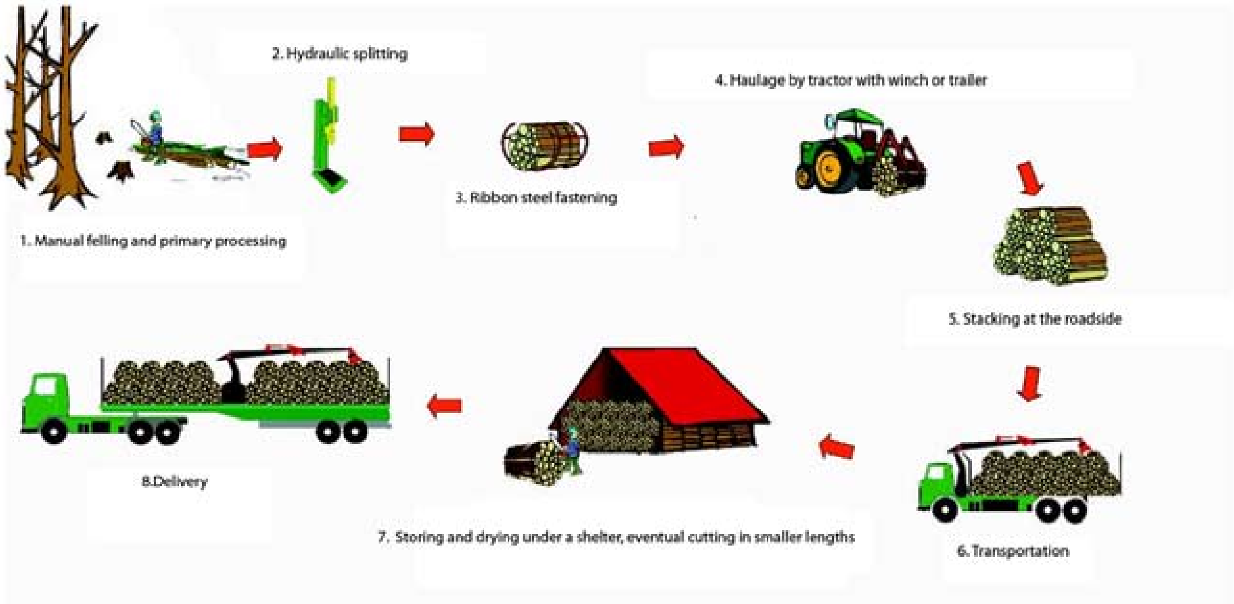


Diagram 8: Production of wood logs fastened with ribbon steel at 1 m (Case 1b)

Phases	(Case 1b)	Operations
1	Operations on felling site	Felling, shedding and topping with a power saw in length of 1 m
3		Splitting of 1 m logs, splitter being driven by a tractor engine
4		Baling with a template for ribbon steel fastening (measuring of wood volume)
5		Haulage of logs by skidder or trailer with a loading crane
		Storing at the roadside, and drying (6 - 18 months)
6	Transportation	Delivery to the customer or transportation to a platform for cutting and/or drying before sale, either manual or mechanized
7	Platform	Eventual cutting of bales in two halves (50cm)
8		Storage and drying under a shelter (6 months)
9	Delivery	Delivery of 0.5 – 1 m bales to the customer

Required equipment (Case 1b):

- Power saws,
- Hydraulic splitters,
- Template for fastening with ribbon steel,
- Agricultural tractor,
- A loading crane with log grips
- A forestry or agricultural trailer
- Road tractor with tip trailer with a loading crane with log grips
- Processing and storing site
- Eventually a building for drying and storing

Mechanized wood log production in the forest (Case 2)

Collection of round logs in 2, 4 or 6 m or treetops, cutting and splitting on site. Mechanized production in the forest is the most efficient logistics with conventional investment and equipment.

Phases	(Case 2)	Operations
1	Operations on felling site	Felling, shedding and topping by manual or mechanized means into lengths of 2, 4, 6 m or whole treetops
2		Haulage and stacking at a storing site – by tractor with winch or skidder, or forestry trailer
3	Operations on storage site	Cutting in lengths suitable for the splitter or cutter/splitter (1 or 2 m)
4		Production of logs by splitting and cutting into lengths of 50, 33 or 25 cm , or by cutting – splitting in lengths of 50, 33 or 25 cm from 2 m logs
5		Deliveries to customers or transportation to a drying platform before sale. Transportation in bulk by lorries.
6	Operations at the platform	Drying by natural means in crates, or in bulk, under a shelter (6 months), or by forced drying in crates (1 - 6 days)
7		Packing on pallets, in solid/net bags, cartons
8	Delivery	Packed or in bulk by small lorries to consumers or palletized to traders

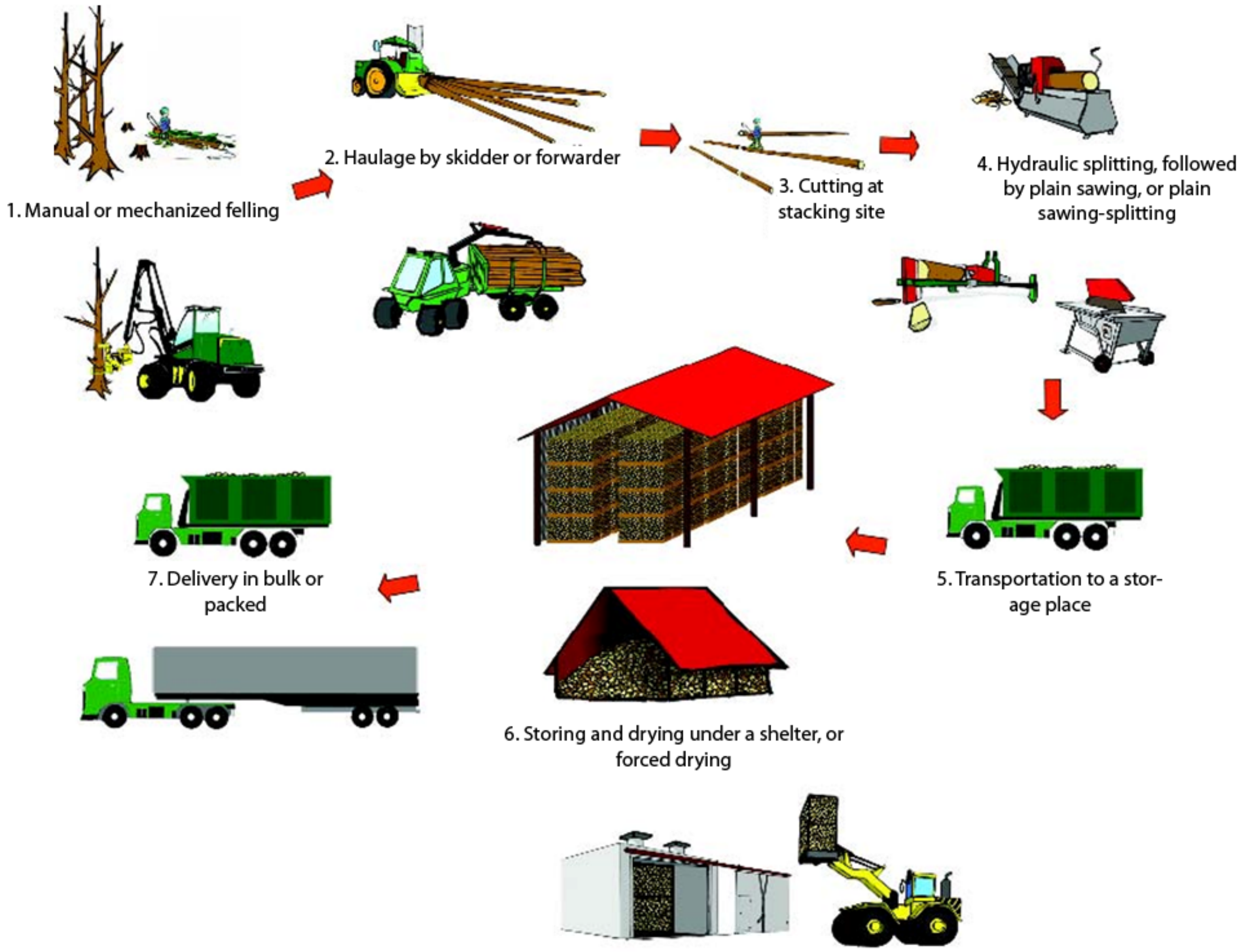


Diagram 9: Mechanized wood log production in the forest

Required equipment (Case 2):

- Power saws and eventually a harvester
- Skidder with winch or grapple, forwarder or agricultural tractor with forestry trailer,
- Hydraulic splitter and band saw, or combined cutter/splitter
- Road tractor and tip trailer, eventually with a loading crane with log grips
- Drying and storing building
- Processing and storing site

Mechanized wood log production in the forest with ribbon steel fastening (Case 2b)

Harvesting of round logs in lengths of 2, 4 and 6 m or treetops, and packing at the storage site by ribbon steel fastening. Mechanized production with packing by ribbon steel in the forest contributes to optimization of the processing operations. In fact, it allows direct delivery of wood logs split as early as in the forest to storages or customers. So, all operations with the exception of drying are taking place in the forest.

Phases	(Case 2b)	Operations
1		Felling, shedding and manual or mechanized cutting in lengths of 2, 4 of 6 m
2	Operations on felling site	Haulage: skidder with winch or grapple forwarder or tractor with forestry trailer
3		Cutting in lengths suitable for the cutter/splitter
4	Operations on storage site	Production of wood logs splitting, then cutting in lengths of 50, 33 or 25 cm cutting-splitting in lengths of 50, 33 or 25 cm
		Fastening with steel ribbons (1 m, 50, 33 or 25 cm)
5		Storage: Stacking with a crane at the storage site Delivery to customers or transportation to a drying platform before sale. Transportation on a trailer platform.
6	Platform	Storage (drying for 6 months)
7	Delivery	Transportation on a trailer platform to customers

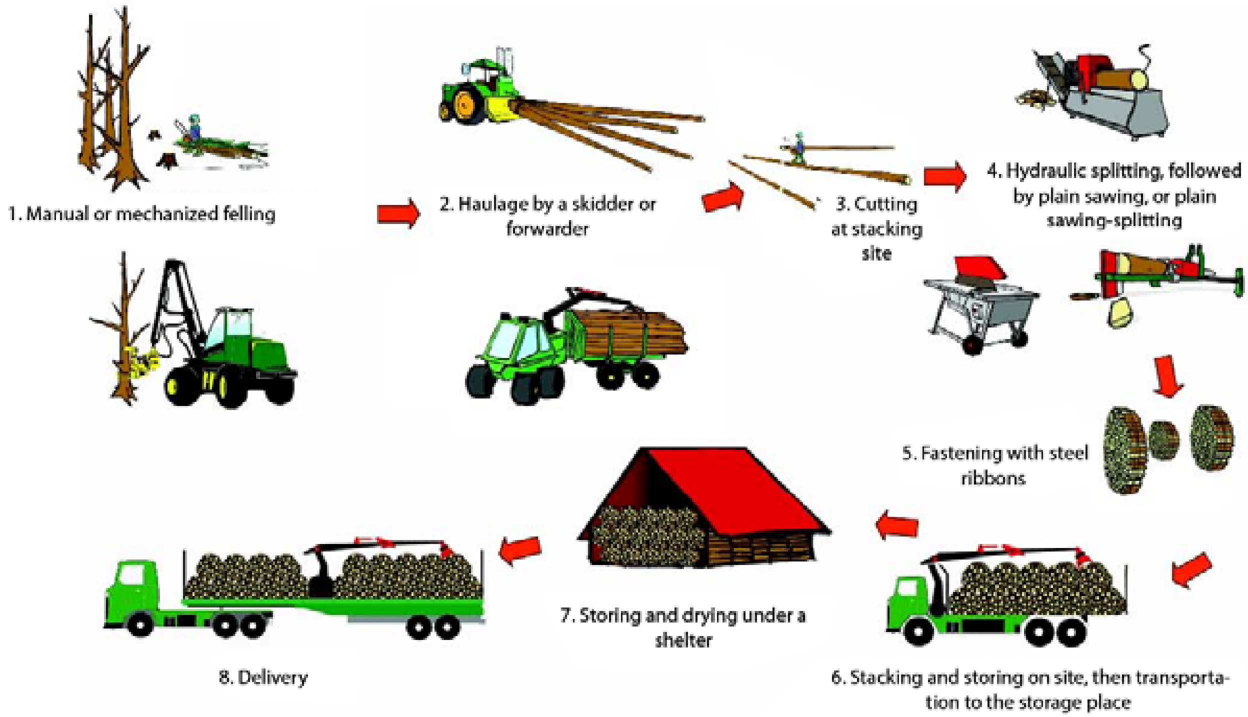


Diagram 10: Mechanized wood log production in the forest with ribbon steel fastening (Case 2b)

Required equipment (Case 2b):

- Power saws and eventually a harvester
- Skidder with winch or grapple, forwarder or agricultural tractor with forestry trailer,
- Hydraulic splitter and band saw, or combined cutter/splitter
- Machine for measuring of wood volume
- Road tractor and tip trailer with a loading crane with log grips
- Drying and storing building
- Processing and storing site

Mechanized wood log production at a platform (Case 3)

Harvesting of round logs of 2, 4 or 6 m or treetops, and packing. The cutting and splitting platform for wood fuel offers the most optimal organization of production. It will prove also to be the cheapest method for large markets, provided that the last phase of the preparation – drying is applied appropriately.

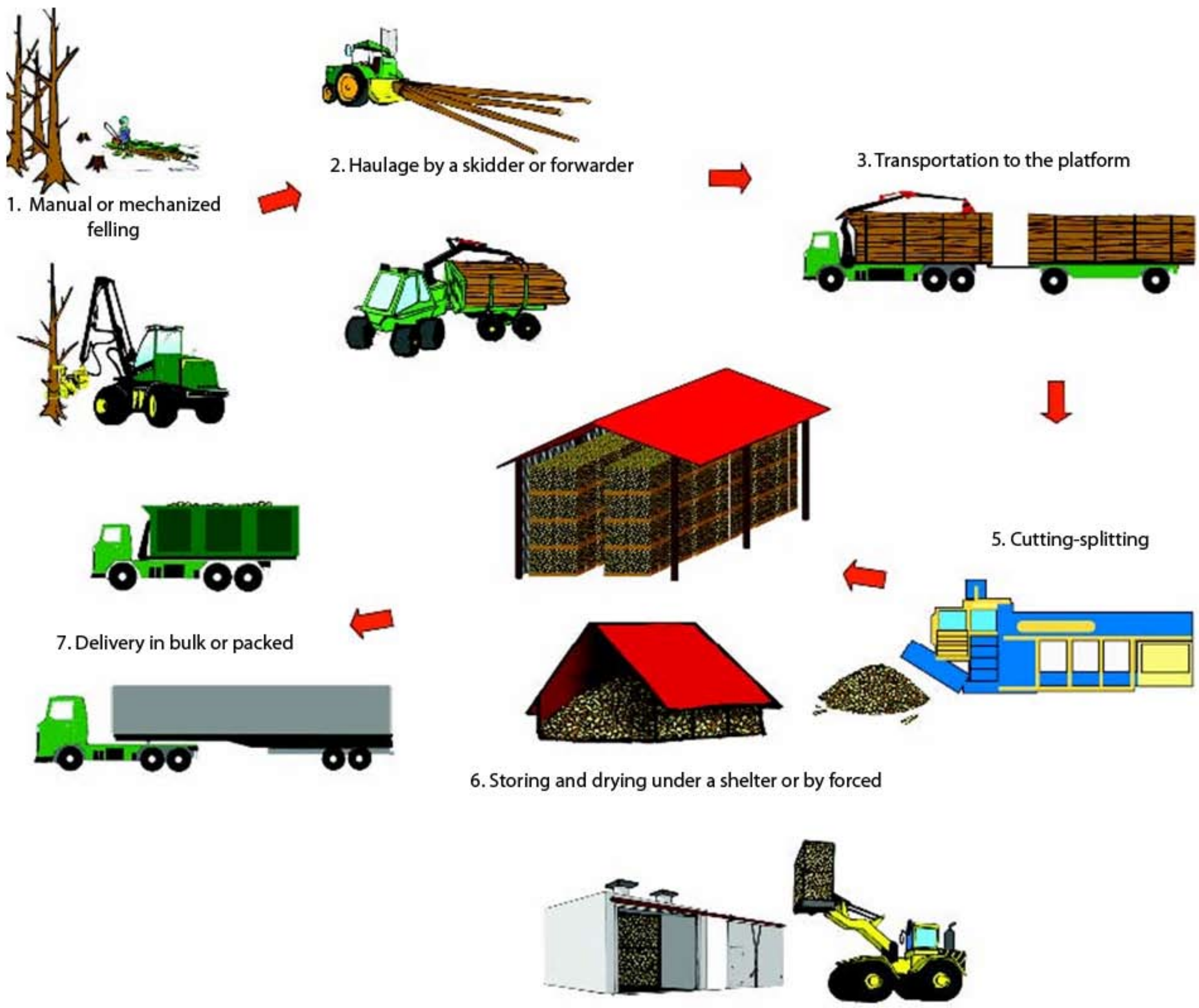


Diagram 11: Mechanized wood log production at a platform (Case 3)

Phases	(Case 3)	Operations
1	Operations on felling site	Felling, shedding and manual or mechanized cutting in lengths of 2, 4 or 6 m or whole treetops
2		Haulage to temporary storing site by a skidder, forwarder of forestry trailer
3	Transportation	Road transportation to the processing platform
5	Operations at the platform	Automatic cutting in lengths of 50, 33 or 25 cm, splitting, processing at a combined cutter/splitter
6		Drying by natural means in crates, or in bulk, under a shelter (6 months), or by forced drying in crates (1 - 6 days)
5		Packing on pallets, in solid/net bags, cartons
7	Delivery	Packed or in bulk by small lorries to consumers or palletized to traders

Required equipment (Case 3):

- Power saws and eventually a harvester
- Skidder with winch or grapple, forwarder or agricultural tractor with forestry trailer,
- Logging lorry or road tractor with a trailer platform
- Stationary system for cutting and splitting
- Building for the drying process, including for forced drying
- Processing and storing site

Wood chip fuel

Drying of wood chips

In general, due to economic reasons it is preferable for drying and stacking to take place before chipping and transportation. Thus, paying in advance for these operations will be avoided. That is why, it will be needed to plan the times of haulage from the felling site and transportation from the stacking site.

Outdoor storage

The most widespread method is to haul the wood for chipping outside the felling site and to stack it at a roadside landing or even on a platform until the time for chipping comes. This time comes at the end of summer when chips are discharged directly in silos, or with the onset of the heating season – for large boiler systems (Continuous flow). Wood branches of lengths 4, 6 m or more are stacked at a right angle to the place where the chipper will be installed. Wood stored in the open will be drying the more quickly, the smaller the size of branches is. In regions with high precipitation rates it is recommended to protect the wood heaps with a cover only at the top. The heaps are arranged at a maximum height of 3-4 m to make handling easier.

In rare cases chips can be stored also in the open. Smaller heaps (not higher than 8 m) have to be removed quickly as early as the beginning of the winter to maintain their quality. This type of storage leads to loss of material and also there is the risk of foreign matter getting inside, if chips are stored directly on the ground, and not a concrete or asphalt pavement. Larger heaps can remain in the open throughout the winter.

Storing of left over branches

Storing in the open

Storage under a shelter

To keep the wood fuel dry or to ensure the appropriate supply, it may be necessary to use some type of a shelter for storage purposes. It can be managed by the fuel supplier or owned by the operator of the heating system.

The availability of dry wood fuel is of importance for the small heating systems and any supplier of such systems is responsible to provide it. Natural drying takes place inside a shelter that has to be well ventilated, but at the same time it has to provide protection against adverse climatic conditions. Also, such facility shall have the necessary suitable provisions to receive deliveries from the delivery lorry. The supplier can use the time for drying to grade up the requires types of wood fuel according to the orders placed with him.

To ensure the normal supply for his customers, irrespective of the delivery volumes, the supplier should have in stock reserves for times of crisis such as sudden changes in weather, severe colds, strikes, breakdown of the wood chipper. It is assumed that to face such unforeseeable circumstances and at the same to maintain the normal quality of the supplied product, quantities of 15 to 20 % over the market demand have to be foreseen. It is very often that logistics fail to ensure this availability.

Photo 31: Storing and drying of wood chips under a shelter

Transportation and delivery of wood chips

Transportation of wood chips from the place of production to the place of storage or consumption is carried out with container lorries (2 containers 30 - 40 m3) or tractors with large tip trailers (80 - 90 m3). It is advisable to use the whole payload of a vehicle to cut down transport expenses, taking into account that wood chips are not a heavy product: 300 to 400 kg per m3 when raw. The other method is to deliver the wood fuel in the form of logs up to the drying platform – for logs of large diameter and high production quantities this conventional logistics can turn out to be the cheapest. In general, the wood fuel for boiler systems of higher rating is chipped just before the delivery with the idea to delay the production costs for this operation as much as possible. For the smaller quantities it is different as often the wood needs to be dry to be suitable for the small boiler systems. That is why, it has to be left on the drying platform for several months (See the next paragraph below). The delivery of small quantities (30 m3) takes place by container lorries or containers with air flow. Containers with an air flow system are different from these for moulded coal and are still not popular in France. They can discharge the chips through a pipe at many meters away. In this way, access of lorries to the silos is easier, especially to these which are located above the ground.

Transportation of wood chips

Delivery by air flow

Wood log fuel

Storing and drying

The moisture content in wood is very high at the time of felling – normally, 45 % without juices and up to 65 % with juices in the poplar and European spruce. To meet consumers' requirements who want a fuel ready for use, it will be necessary to decrease the moisture down to 20 - 30%.

The moisture content is affected depending on:

- **Timing of felling**: in the Northern semisphere felling takes place mainly from November to March, the period of the juice descent, in order to make the best of this natural process in trees. This decreases the moisture content of wood with 10 - 15 % in a natural way.
- **Shaping:** splitting and cutting in smaller lengths will speed up the loss of moisture. Wood fuel has to be split in quarters and stacked in the open with the shortest possible pieces early in the spring. Round logs (not split) dry more slowly.
- **Climate:** wood moisture will decrease much more

quickly at dry and hot weather than in a wetter climate.

- **Type of storage:** if the wood fuel is not in the shade or exposed to rain, it will dry very quickly. But ventilation is the most important factor in drying. So, it is advisable to store wood fuel inside a facility well ventilated.

The maintenance in stock ensures supply for customers irrespective of the seasonal obstacles resulting from exploitation of forests. It also allows drying of wood which means pure increase of heat value, and therefore of its quality.

Storing and drying in the forest or at the roadside

It is possible to stack wood in the forest or by the roadside and leave it there to dry. This allows to minimize storing and transportation costs. But it will take longer time for wood fuel exposed to the climatic sudden turns to dry. To achieve a moisture content suitable for use it will be necessary to wait 1-2 years. In addition, there is the risk of damages to wood during the above period – lichen at the bottom of the heap, insects, sun which will deteriorate its quality.

But still, if there is no other way, wood log have to be split in quarters to facilitate drying. Cutting of wood in lengths suitable for use will further reduce the time necessary for drying. It is also necessary that wood is directly stacked on the ground, but on a dry place, and heaps to be exposed to the sun and wind, and if possible, be covered with a material letting in air. The quarter pieces can be fastened with ribbon steel to make further processing easier. When wood is stored in the forest, stealing is often a problem. So, this fact has to be taken into account.

Natural drying under a shelter

Wood log fuel shall be stored under a sufficiently large and high shelter for protection against unexpected changes of weather and to make further processing possible. Wood shall be stacked on a dry ground to prevent damages and reduce propagation of parasites. If wood is arranged in rows, there shall be a distance of at least 20 cm between heaps and wall to have good ventilation. Edges of heaps shall be supported against poles or other solid supports to ensure stability of the structure. Drying of split wood logs under a shelter decreases 2-3 times the time necessary for natural drying. Wood stored in accordance with these rules and cut in short pieces will dry two-three times faster that wood logs of l m length left in the rain and stored directly on the ground. After 6-8 summer months and storing under these conditions the wood fuel will be ready for use. Choice of place of storage.

Factors that have to be accounted for to have an appropriate storing and drying:

- flat surface to ensure stability against displacement
- maximum exposure to wind as it is the main drying agent
- good access to the storage place

Forced drying

Forced drying is another method for drying of wood log fuel. There are different alternatives for forced drying such as drying with cold air (fan), hot air or water steam. However, drying chambers in the wood fuel market are still very expensive and a few persons can afford to make such investment. Yet, there are many examples in Europe. Forced drying considerably shortens the time necessary for drying and is suitable for the very dry packs of woods sold in the market. The main reason for the use of this method is the drying rate which is much higher than this of the conventional drying. We can produce completely dry wood fuel for 4 days at 24 h cycle. This is a big advantage since it highly reduces storage expenses, if we want to have really dry wood.

Packing of wood log fuel

As with any other product, packing complies increasingly more with the customer's practical needs. The more sophisticated packing is, the more expensive it will be. This has to be taken into consideration at the earliest possible phase of the production cycle to reduce expenses. Wood log fuel is sold in various quantities and ways:

Stacked heaps in cubic metre

Wood log fuel is sold by cubic metre in the form of heaps stacked in the forest, at the roadside or in a delivery lorry.

In bundles

Bundles are wood logs for fuel tied with rope or belts in a form produced with a template. This type of packing allows to take easy measurements, palletize the logs, cut the logs in lengths of 50, 33 or 25 cm upon delivery, and make shifting by customer easier.

On pallets

Palletized wood logs for fuel are stacked heaps fixed on a pallet by means of ropes, belts, wooden or steel supports, or shrink-wrapped in plastic film.

In bulk

Wood logs for fuel are delivered by lorry without being arranged in a special way. This method is used mainly with short logs.

In net/solid bags or crates

In general, bags of small volume sold at large supermarkets or service stations contain mainly short logs (25 - 33 cm) or ignition sticks.

Heaps in cubic metre at the roadside

Palletized wood log fuel

Wood log fuel packed in net bags

Palletized wood log fuel

Transportation and delivery of wood log fuel

This is the last phase of the supply. Transportation can be done by various means. The most widespread is the delivery lorry with a crane + trailer, if the quantity is larger. Transport charges are generally high mostly, if wood logs are in bulk, that is, not arranged tightly. The choice of type of transportation before and after preparation of the wood fuel has to be made, taking into consideration minimal handling and maximum convenience for the customer.

Light delivery lorries

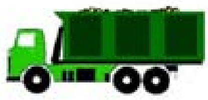
 

Diagram 12 (left): Platform lorry with crane
Diagram 13 (right): Container lorry

Heavy-duty delivery lorries

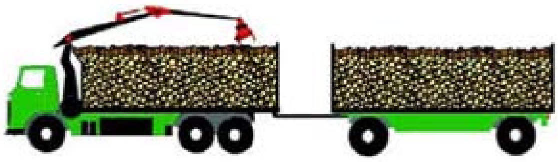


Diagram 14 : Heavy-duty delivery + trailer

Tractor + semi-trailer

Diagram 15 : Platform with crane

For more information
Please visit the wood energy portal
www.itebe.org

A place for any visitors

- General information about the whole production cycle of energy from wood (supply with biomass fuel, individual and collective heating systems running on wood fuel)
- A monthly electronic letter ITEBE INFO
- Year-book for professionals in the wood energy production,
- On-line library, topic forums, photo gallery, small advertisements, withdrawal of documents, list of Internet sites for wood energy.

A place for professionals Interactive platform for exchange through Internet for acquiring and distribution of professional knowledge, technical documentation, research, reports, events and turns in the experience from wood energy production.

Practical applications of wood energy
Range of information
1. Guide 2004 on wood energy
2. Domestic heating: the choice of wood fuel heating

Range of guides
1. List of regulations on wood energy in France
2. Tabulator for use of forest wood chips
3. Commercial characteristics of wood fuel

Range of practical applications of heat wood
1. Production of heat wood
2. Production of heat wood and work safety
3. Planning of central heating system running on wood

Range of practical applications of wood chips
1. Production of forest wood chips for energy
2. Production of forest wood chips for energy and work safety
3. Assistance for preparation of contracts for supply of wood fuel for boilers
4. Planning of automated boiler house fire on wood chips, of output below 300 kW
5. Planning of integration of a silos or feed chute for wood chips
6. Conceiving of a heating system running on wood
7. Getting energy value from waste energy

Use of wood for energy

Technologies for energy conversion from wood: thermal and electric conversion, cogeneration

The wood combustion process takes place generally in three stages which are depending on temperature of the process:

- drying
- decomposition
- combustion

From the point of space inside boilers running on wood, these stages run separately, while especially in boilers of larger size with automatic feeding for the travelling grate, these processes take place in separate sections of the grate. Still, there is also a separation in time of the phases of evaporation of volatile matter (pyrolysis) and its oxidation (combustion) in the systems of the first type.

From the point of time, Diagram 1 shows quality data for the process of combustion of small biomass particles. When size of particles increases, a certain overlapping of separate phases takes place. An enhanced overlapping of phases at the highest extent is found in boiler system fired on wood.

Water contained in wood starts to evaporate even at temperatures below 100 °C. As evaporation is a process which uses the energy released during the combustion process, temperature in the combustion chamber decreases and slows down the combustion process. It is found that in boiler systems on wood, for example, the combustion process cannot be maintained, if wood has a water content over 60 % by weight. In fact, "fresh" wood requires such quantity of energy to evaporate the water contained in it that the temperature in the combustion chamber drops under the minimum level required for maintenance of combustion. For this reason, water content of wood fuel is among the most important quality parameters.

In addition to the combustion process, water content of wood also has an impact on the adiabatic temperature of combustion and quantity of gas released for the production of an unit of energy. Wet wood requires longer drying process before the first two consecutive phases of pyrolysis/gas generation and combustion and this means that a larger combustion chamber would be needed. Therefore, information about the water content of wood fuel at the input of the combustion chamber is of importance for the appropriate regulation of the compressed air systems operated inside the combustion chamber and for the adequate design of sizes and geometry of the boiler which will ensure sufficient residence time of gases in the combustion chamber to obtain their complete combustion. Also, the thermal efficiency of the process (proportion between heat produced by boiler and energy content of fuel) decreases with rising of water content of wood - a condition that can be partially compensated for in systems of bigger capacities through the use of a condensate module.

Thermal decomposition (pyrolysis /gas generation)

After the drying process at a temperature of about 200°C the wood undergoes thermal decomposition which leads to evaporation of the volatile matter contained in it. Volatile substances make up over 75 % by weight of wood and because of this it can be asserted that their burning will mean basically burning of the gases included in their composition. Rate of evaporation of gases increases with temperature rise. First

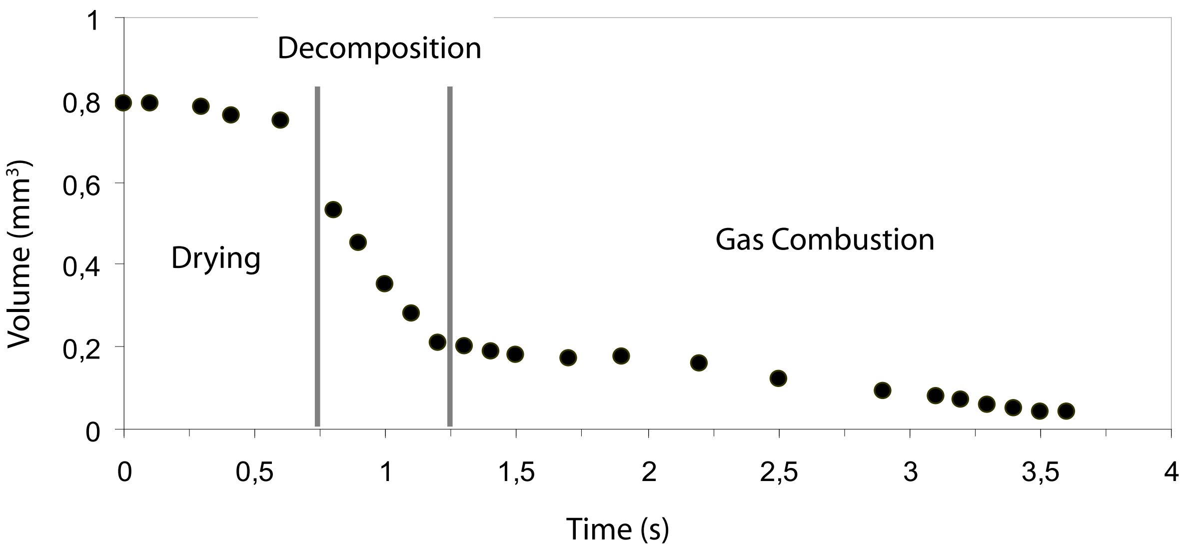


Diagram 1 – Combustion of small particles of biomass passes through three clearly divided stages components of wood that will be subjected to decomposition are hemicelluloses and then cellulose. Hardwood (beech, white acacia) have a higher content of hemicelluloses as compared to softwood (coniferous trees) and therefore loss of weight as a result of wood decomposition is earlier and more expressed in the former. At 400°C the greater part of volatile matter is released and the rate of evaporation is quickly decreased. Still, there is a certain loss of wood mass as early as at 400°C and 500°C due to decomposition of lignin which takes place throughout the process of evaporation, but most of its decomposition occurs at the highest temperatures. The beech wood which has the highest content of hemicelluloses and the lowest content of lignin, releases the lowest quantity of carbon emission during burning. In boiler systems this phase is supported by the flow of preheated primary air.

Combustion

Combustion is complete oxidation of gases and this is a phase that starts at 500°C and 600°C, and continues at temperatures up to about 1000°C. Within the range of 800°C - 900°C fixed carbon burns and also resin burns together with it.

The rule of the three T

The lack of unsuitable conditions will lead to incomplete combustion of wood and consequently to an increase of noxious emissions. The main causes for incomplete combustion are the following negative conditions:

- unsuitable air-fuel mixture inside combustion chamber
- general shortage of oxygen
- very low temperature of combustion

Therefore, quality of combustion depends on three main factors: **Time**, **Temperature** and **Turbulence.**

These three parameters are closely related. It is important to have always adequate fuel in the boiler, and hot smoke in the second combustion zone and heat exchangers at the suitable time. Temperature has to reach sufficient high levels in order to provide conditions for the separate phases of combustion and particularly the phase of gas oxidation. And finally, it is of significant importance to ensure an adequate air flow to the separate zones and during the different phases of combustion through the supply of a flow of primary, secondary and eventually tertiary air.

Combustion is complete, at least theoretically, when all components of the fuel have reacted with oxygen. Otherwise, if air supplied is not sufficient, part of the energy contained in the fuel will remain in the by-products of combustion such as, for example, carbon monoxide, and in such event combustion will be incomplete.

Theoretically, the required quantity of air is the quantity needed to obtain complete combustion, that is, burning of all fuel components. The ratio between the theoretical and supplied quantity of air is referred to as coefficient of excess air (λ), and this wood coefficient varies in the range 1.25 - 1.4, which in another words means an excess air of 25 % - 40 %.

Complete combustion, of course, is only a theoretical concept, especially in solid fuel, as is wood, in so far as obtaining the adequate proportion of the air and fuel mixture in such limited period of time is a problem. Incomplete combustion leads to incomplete combustion of gases and increase of unburned substances, both organic and inorganic, and this results in raised levels of CO and particulate matter in the exhaust gases.

In the last 30 years we have experienced a gradual increase in the performance of boilers fired on wood and this resulted in a significant reduction of carbon monoxide and other noxious emissions (particulate matter, volatile organic compounds, nitrogen and sulphur oxides).

The following two diagrams show the results from a range of measurements taken over a long period of time by BLT, a renowned research institute from Wieselburg, Austria (www.blt.bmlf.gv.at). This institute certifies emission levels and performance of fuel installations on wood according to European regulations. It is of interest to note the reduction in the levels of dispersion in both diagrams within the course of time as a demonstration of more frequent improvements in the design specifications of boilers and the reporting of an average efficiency of over 85 % and CO levels very often below 50 мг/Nm3 for 2004. In addition of CO monitoring, there are a number of other parameters of exhaust gases that could be used to control and assess quality of combustion.

Percent content of O2 has to be in the range of 5 - 8 %. The quantity of CO2 has to be more closely to the theoretical value which is 20.4 % for wood. But there is still a close relation between O2 and CO2 and so at O2 values of 5 - 8 % the corresponding CO2 values are 13 - 16 %.

The NOx quantity is affected mostly by temperature which causes the production of the so-called thermal NOx. Because of this, temperature has to be in the range of 850 - 1200 °C. And finally, another important parameter is also the temperature of exhaust gases which has to be maintained below 150 - 170 °C.

Of course, combustion is greatly dependent also on quality of fuel and type of boiler. In general, the more homogeneous the wood fuel is in terms of size and water content, the better its combustion will be.

Industrial installations, small and medium heating and heat transfer grids

Wood fired boiler systems can be divided in the following categories depending on the type of the wood fuel used, generating capacity and boiler feeding system.

- Boilers fired on wood logs, manual feeding
- Small boilers fired on wood pellets, automatic feeding
- Small and medium sized boilers fired on wood chips, with inclined (i.e. fixed) grate and automatic feeding with a feed screw

1. In thermodynamics the adiabatic process is a thermodynamic change within a physical system without any loss or gain of heat, that is, no exchange of energy with environment.

- Medium and large sized boilers with travelling grate and automatic feeding with a feed screw or a pusher

WOOD LOG FIRED BOILERS

Wood log fired boilers can be divided in two categories depending on the combustion principle: bottom combustion and reverse combustion.

Bottom combustion boilers normally use natural draught and pressure drop requires to feed primary air from outside which is then transferred to the combustion chamber; flue gases are transferred to the bottom part of the furnace (secondary air) and after it to the second combustion chamber. As the air flow passes under the furnace, it is very important to have the wood arranged in the proper way so that air could move uniformly to the combustion zone.

Wood log fired boiler with bottom combustion and natural draught (Guntamatic – KOBRA model).

1. Primary air
2. Secondary air
3. Combustion chamber
4. Heat exchanger
5. Draught control system

The reverse combustion boilers with induced draught are the most innovative solutions for boilers in terms of technology. Gases are discharged through a hole under the furnace into the second refractory lined combustion chamber as a result of a forced pressure drop created by a fan located at the bottom.

The resistance of the flue gas flow is high and it requires an ID fan with electronic controls. The fan allows for precise modulation of the primary flow air (normally, preheated) and secondary air flow inside the combustion chambers. Normally, there is a lambda probe in the first section of the flue stack for continuous measurement of O2 concentration in the flue gases and regulation of the fan, and in boilers with automatic-feeding - the rate of fuel feeding. This oxygen concentration sensor is exceptionally useful in wood log and wood chip boilers since these fuels have typically variable water and energy content. Also, the lambda probe helps to obtain a continuous maintenance of a combustion process of high performance and consequently minimize harmful emissions. Wood fired boilers are normally ignited manually, however, more advanced models have also automatic ignition.

Location of the three phases of wood combustion in a reverse combustion boiler

1. DRYING
2. THERMAL DECOMPOSITION
3. COMBUSTION

Reverse combustion boilers with induced draught (Guntamatic – model BMK)

1. Preheated primary air
2. Secondary air
3. Turbo combustion chamber
4. Vertical turbulators
5. Lambda probe
6. Induced draught fan with electronic controls
7. Electronic control board

Reverse combustion boilers with induced draught (KÖB – model Pyromat ECO)

1. Primary air
2. Secondary air
3. Heat exchanger with vertical turbulators
4. Lambda probe
5. Induced draught fan with electronic controls
6. Electronic modules connected to the control panel

Hot Water Accumulator (known also as buffer tank)

In wood log fired boilers it is very important to provide energy storage that is adequately sized depending on a number of heat engineering parameters.

In fact, often the wood charge gives a quantity of thermal energy that is higher than the daily heat needs, especially in spring and autumn intermediate seasons and in summer. So, to avoid dissipation of this thermal energy in the surrounding space at an obvious loss, instead it can be diverted and stored in an accumulator.

The accumulator allows for: - optimization of combustion which will extend boiler service life, - maximum useful absorption of heat, - programming of room heating in the early morning hours and availability of larger quantities of water for sanitation needs at a single wood feeding[2], connection of the boiler to a solar heat installation and thus shut down of the boiler in summer.

Sizing of the accumulator shall be in accordance with the following formula from the EN 303-5 standard:

$$VSp = 15 \times TB \times QN \times (1 - 0,3 \times Qh/Qmin)$$

VSp	Tank volume
TB	Period of combustion [h]
QN	Nominal thermal power [kW]
Qmin	Minimal thermal power [kW]
Qh	Consumption in heating of a medium-size building [kW]

Example: Single family house

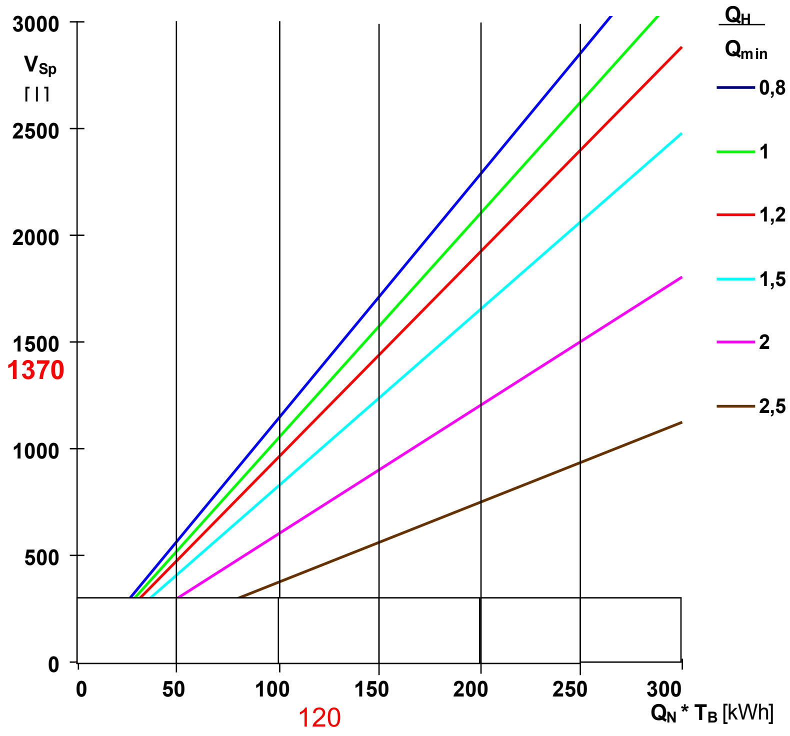
TB	6 h (hardwood)
QN	20 kW
Qmin	10 kW (50% nominal power)
Qh	approx. 8 kW per 180 m² (new building)

15 x 6 x 20 x (1 - 0.3 x 8/10) = 1,368

This installation will require an accumulator of volume 1,500 litres

2. When accumulation is well calculated, in the summer period a single charge of wood can cover the needs of sanitation water for about 4-5 days.

The following diagram shows the change in the accumulation volume as a function of the kWh produced by the wood charge. The straight lines gives the relation between the average consumption for heating of the building and the minimal thermal power, the latter being 50 % of the nominal generation power.



WOOD PELLET FIRED BOILERS

The wood pellet boilers can fully meet the annual heat needs of a single or double-family house. In general, there is an option to have either a compact semi-automatic or fully automatic system.

The compact semi-automatic system consists of a boiler with a fuel tank next to it (this can be a tank for daily or weekly needs), normally with manual feed. A large quantity of fuel (for example, packed in bags) have to be kept in stock in another place. Pellet fuel is automatically fed to the combustion chamber by the feed screw.

The fuel tank has to be of a volume at least 400 litre. Then the fuel can be sufficient for up to one month depending on the dwelling area to be heated and outside temperature. In an ideal case, the owner will be informed about reaching of the lower level of the fuel charge by an indicator fitted either on the boiler or in a remote place, and then the system should remain in operating mode to control the shut down temperature. In Austria, compact systems are required to have a fire protection to keep off the flame (MIF) and a thermal sensor (ST).

In the **fully automatic system** a hopper is located near the weekly fuel tank and is automatically loaded with larger quantities of fuel (for example, for one year; feeding is by means of a feed screw or a pneumatic extraction system. In an ideal case, the hopper is loaded, for example, by a tank lorry delivering wood pellets one time every year. If conveying of fuel from hopper to boiler is by a feed screw, then the hopper has to be near the boiler room and also safeguards shall be installed against burnback or fire traveling back from the combustion area along the incoming fuel stream. For example, one such device could be a gate lock, or air valve lock, or shutdown device. In Austria fully automatic system fired on pellets are required to have also a fire sensor and a temperature sensor.

The pellet hopper has an inclined floor, often made in wood or laminated material, at a grade of at least 40°-45° so that pellets can slide in a trouble-free way. The inclined area should not be too long and its surface shall be smooth and polished. The sizes of the hopper can be quickly calculated from the following formula:

Hopper volume in m³ = 0.9 x power, kW

Therefore, a pellet boiler of rating 15 kW will need a hopper of about 13.5 m3. If the room height is 2.3 m the hopper will occupy an area of 6 m2 (sizes 2x3x2.3).

An example of a pellet automatic installation with a pneumatic feed system is the Ökofen suction system. The cyclone separator is installed at the right side) and is connected to two hoses of length up to 15 m.

Bag hopper

This type of hoppers is suitable for indoor or outdoor installation. These are very flexible and practicable for storage applications. They are installed easily and their airtightness ensures excellent protection against penetration of dust and water. Bag hoppers are connected to the weekly fuel tank by means of a pneumatic system. They are available in volumes from 2.8 to 5 tonnes.

WOOD CHIP FIRED BOILERS

The wood chip boilers are divided in two categories:
1. boilers with inclined grate
2. boilers with travelling grate

Boilers with inclined grate

These are small to medium-sized boilers rated from 25 kW up to some 400-500 kW suitable for domestic applications in small heat transfer systems.

They have a fixed combustion chamber with different types of feeding. The most widespread boilers are these with grates with bottom feeding by means of a pusher (Unterschub-feuerung) where primary air is active under the grate and contributes to drying of the wood and gas production, while the secondary air is active under the grate and contributes to efficient oxidation of released gases.

HARGASSNER W 25-55

1. Bottom feed with pusher
2. Plate for concentrated flame
3. Heat exchanger
4. Turbulators
5. Warm gas flow
6. Flue stack
7. Lambda probe
8. Protected heat exchanger (EN 303-5)
9. Motor of feed screw and heat exchanger cleaning system
10. Ash removal screw
11. Control module for the heat exchanger cleaning system
12. Ash section
13. Primary air
14. Preheated secondary air

Boiler foundation with fixed grate. Openings at the bottom for primary air on the grate and side openings for secondary air on the refractory lining.

Wood chip storage. It consists of a hopper, normally with a square bottom, from which wood chips are taken out by a system with a spring mechanism or hinged shoulder. The system feeds the chips to a screw conveyor connected to the feed screw, and the feed screw moves the fuel to the combustion chamber. The screw conveyor and feed screw are joined through an open vertical drop which serves to prevent fire from moving from feed screw to the screw conveyor. When the temperature threshold is exceeded the fire protection will trigger and seal off the feed screw from the screw conveyor by means of the safety open vertical drop.

1. Rotary system with spring mechanism, 2. transmission, 3. screw conveyor, 4. motor feed screw, 8. ignition system (Hargassner).

The wood chip storage can be organized in various ways depending on the boiler system equipment. Most economical are solutions when it is located inside an existing room or an outdoor wooden structure is constructed on a cement foundation next to the boiler system.

Some companies are offering also mobile modules plug&play (Ecoenergie Srl.).

Hopper size has to ensure an independent operation of at least 15-20 days in winter.

In small installations the rotary system taking the wood fuel out of the hopper makes a circle of diameter from 3to5m.

A boiler system rated at 100 kW can use approximately about 2 msr/day. Therefore, a hopper of capacity 60 m3 will ensure independent running of the system for a month.

The daily consumption of a heat boiler can be easily calculated on the basis of the produced kWh, the lower heat value of the wood fuel used and its weight. Still, for a small boiler system the following formula can be used at a moderate level of accuracy for quick calculation:

Boiler rating kW x 2.5 = Annual consumption of wood chips, msr/year (softwood, G30, W30)
Boiler rating kW x 2.0 = Annual consumption of wood chips, msr/year (hardwood, G30, W30)

Importance of quality of wood chips. Boiler systems running on wood chips and fitted with an inclined (i.e., fixed) grate will require wood chips of uniform size (class G30 and G50) both because of the limited size of the grate and the risk of blocking the screw conveyor or feed conveyor when chips are of different sizes. To avoid similar problems, a rotary star or crusher is installed depending on the arrangement of the safety open vertical drop.

3. The special thing is that the boiler is fitted with a sensor measuring the thermal power of fuel (hardwood/sofwood chips, pellets, shavings) to regulate automatically the speed of screw feeding.

Sizes of wood chips according to ÖNORM 7133 standard.

Total fuel 100%			Class sizes of wood chips		
			G 30 (fine)	G 50 (medium)	G 100 (large)
Large fraction 20%	Max. cross section	cm^2	3	5	10
	Max. length	cm	8.5	12	25
	Nominal diameter* of screen holes - large	mm	16	31.5	63
Main fraction from 60% to 100%	Nominal diameter * of screen holes - medium	mm	2.8	5.6	11.2
Fine fraction (incl. powder) max. 20%	Nominal diameter * of screen holes - fine	mm	1	1	1

** Denotes size of wood chips which will pass through screen square holes of side size in mm as specified.*

Water content shall not be higher than 30 %. These boiler systems have a poor thermal accumulation as their combustion chamber and water in the heat exchanger is of limited volume, and consequently the feeding of wetter fuel would lead to significant lowering of combustion temperature. Also, too much moisture can be an obstacle to the ignition as these systems are fitted with a device for automatic ignition using an electric blower to blast air heated up to 700 - 800°C over the wood chips for several minutes.

Boilers with travelling grate

These are boilers of medium and high rating from 500 kW to several MW for industrial-scale applications and heat transfer systems. Recently, small boilers with a travelling grate are also available in the market.

In boilers with a travelling grate the grate is not fixed, but is traveling more or less at a certain grade. These are boiler systems suitable for burning of wet wood chips with variable sizes and increased ash content. They can burn also various wood mixtures, but it is not advisable to use mixtures of wood and grain crops, grasses and straw as they show a typically different behaviour in combustion, low water content and low temperature of ash melting.

In boilers with a **traveling sloped grate** scrapers are moving horizontally forward and backward and gradually shift wood chips forward over the grate.The boiler has a number of complex mechanisms which ensure uniform distribution of wood chips and burning fuel over the whole surface of the grate. This is of exceptional importance to provide a flow of primary air uniformly distributed over the whole surface of the grate. Otherwise, slag could be produced (see the illustration), increased quantity of volatile ash and much excess oxygen.

Also, conveying of the wood chips over the grate has to be carried out in the possibly steadiest and uniform manner so that the burning fuel shall remain uniformly distributed to ensure continuous and uniform combustion and avoid the formation of zones of incompletely burned material.

Phases of combustion take place in three separate parts of the grate and because of this the primary air below the grate and the speed of the grate are modulated.

The grate can be fitted with a water cooling system to minimize melting and formation of slag in melted ash which occurs when the temperature in the combustion chamber is higher that the temperature of melting of wood ash (about 1140°C-1340°C), and also to extend the operation life time of the materials used in the boiler construction, especially the refractory parts.

Phases of combustion are divided by separation of the primary combustion chamber from the secondary combustion chamber to prevent mixing with secondary air and separate gas production and oxidation zones. The more efficient mixing of the secondary air with the fuel gas is, the lower will be the excess oxygen necessary for the process of burning and consequently the combustion process will be more efficient.

A modern boiler with travelling sloped grate (UNICONFORT model Biokraft)

1. Drying zone
2. Gas production zone
3. Oxidation zone
4. Combustion chamber with primary air
5. Combustion chamber with secondary air
6. Heat exchanger
7. Auxiliary burner
8. Hydraulic pusher
9. Primary air fans

10. Secondary air fans
11. Tertiary air fans
12. Ash removal screw

The **wood chip storage** normally has a rectangular bottom and unloading system with a scraper. In addition, the feed screw can be replaced with a hydraulic pusher which is of significant importance when non-uniform wood chips are being used with sizes predominantly not complying with the fraction sizes.

An example of a layout of components of a boiler system with a travelling grate rated 700 kW (UNICONFORT model Biotec)

1. Wood chip hopper
2. Wood fuel unloading with scraper
3. Motors of unloading system
4. Screw conveyor
5. Feed hole
6. Boiler
7. Multicyclone
8. Flue gas aspirator
9. Flue stack
10. Manifolds

Combined production of heat and electrical energy - Small-scale applications

The combined production of heat and electric energy (CHP, Combined Heat and Power or cogeneration) from wood biomass is by means of closed thermal processes in which the combustion cycle of the biomass and production cycle of electric energy are separated by the phase of heat transfer from the combustion gases to the transfer medium used in the second production. This is done so to avoid damaging of the internal combustion engines by the aerosols, metals and chlorine compounds contained in the gases released in the combustion process.

To achieve steady energy development and environmental protection, the production of electric energy from biomass fuel shall involve also production of heat energy according to the following principle: "Production of kWel only when there is a need also of its heat equivalent!" Otherwise, the process will lead to waste of resources and therefore loss of huge quantities of energy. And so, cogeneration requires use of heat and electric energy at the same time, something which is not easy.

The following three processes of cogeneration will be described below:

- ORC turbogenerator (Organic Rankine Cycle)
- Strirling engine
- Steam engine

Orc Turbogenerator (500 - 1100kWe)

The first production cycle takes place in an ordinary boiler with a travelling grate fired on biomass, with the use of diathermic oil as a heat transfer medium. It has a number of advantages among which are: low pressure in boiler, high accumulation, steady operation at fuel charge with variable parameters, simple and reliable controls. In addition, the temperature used in the heated part of the system (about 300°C) ensures a long service life time for the diathermic oil. And also, the use of diathermic oil makes it possible to operate the boiler system without the mandatory attendance of a qualified and certified operator as required in steam systems in many European states.

The heat from condensation in the turbogenerator is used to produce hot water at temperature of about 80 – 90°C which is a temperature level suitable for central heating and other applications at low temperature (drying of whole wood, drying of wood shavings for pellet production, cooling by absorption systems, etc.). The principle of operation of an ORC turbogenerator is based on the Rankine closed cycle in which silicone oil is used as a transfer medium.

ORC turbogenerators using silicone oil as a transfer medium showed net electric energy efficiency of about 18 % when running at nominal temperatures of the cooling water (60°C/80°C). Approximately 79 - 80 % of the heat produced by cogeneration is transferred to the cooling water and the calculated losses of electric energy and heat are only 2 - 3 %. This means that the total thermal efficiency (efficiency of the 1st principle) of systems with ORC turbogenerators is in the range of 97 - 98 %.

The ORC turbogenerator can operate without any problem at a partial load of down to 10 % from the nominal rating and achieve excellent energy efficiency at incomplete loading and an almost steady efficiency at a load down to 50 % of the nominal.

The total efficiency of a boiler system with diathermic oil is also dependent on the presence of an economizer. Modern boilers with diathermic oil can achieve total efficiency (oil energy not used/lower heat value) above 80 % and electric energy efficiency close to 15 %. When an economizer is installed the total efficiency can reach 90 %.

Stirling Engine (20-100kWe)

The Stirling cycle is a thermodynamic process in which heat energy is converted into mechanical energy.

The Stirling engine belongs to the group of engines with hot air in which the travel of the piston is not due to the internal combustion of gas, but is the result of the volume expansion of a constant gas mass closed in a chamber which is expands under the energy transferred from an external heat source (wood chip boiler).

And so, the creation of draught force is separated from the combustion chamber (heat source) which can be run on any type of fuel and, independently of the process of creation of draught force, can be optimized with regard to the emissions.

The Stirling engine can use helium or hydrogen as transfer medium. The use of helium as a transfer medium contributes much to electric energy efficiency. However, it is very important to use appropriate insulation.

Combustion of the wood fuel takes place in a boiler and combustion gases are conveyed to the heat exchanger of a Stirling engine where part of their energy content is used to transfer heat to the transfer medium in the engine. The combustion gas is discharged out of the heat exchanger at a temperature of about 850°C.

The residual heat contained in the combustion gas is used in an air preheater for preheating of the fuel air. The air preheater is an important component in the cogeneration process with a Stirling engine for enhancement of the electric energy efficiency. After leaving the air preheater the combustion gas is conveyed to the economizer and the heat is transferred to an eventual heat transfer system or is used as a process heat (heat for the start of a new process).

At the present, the electric energy efficiency of this cogeneration system with a Stirling engine is approximately 12 %.

Steam Engine (50-1200kWe)

This is an alternative to the steam turbine and is suitable for use only in large-scale systems.

The steam engine with pistons is a machine of a modular type, with one to six cylinders in different engine arrangements. A single-stage or multi-stage engines are used depending on parameters of the steam produced. The ratio between intake and discharge (also known as exhaust) pressure is normally 3, maximum 6 per an expansion phase.

Engine efficiency is depending on steam parameters. It can vary in the range from 6 - 10 % to 12 - 20 % for a single-stage and multi-stage engine respectively. The intake pressure is normally between 6 - 60 bar, while discharge pressure can be 0 - 25 bar.

An example of an application of a steam engine in a heating system running on wood chips, is that of one located in the community of Fondo, province of Trento, Italy and commissioned in 2004. The steam produced from the boiler (3.5 + 2.5 MWt) is conveyed through the engine (220 kWe, Spilling Energie Systeme GmbH) and produces electric energy by the generator. The discharged steam (of pressure below 0.5 bar) is conveyed to a steam/water heat exchanger and then to a heat transfer grid. The parameter which regulates the operation of the system when run at parallel with the heat transfer grid is the steam pressure at the discharge. A bypass with a control valve is connected to the steam engine. If the pressure at the discharge end of the engine drops despite of running at full power, the reducing valve will open again until the required pressure level is reached. When the engine is shut down the steam is taken out to the steam/water heat exchanger through the reducing valve.

The steam engine is started manually. Adjustment of the revolutions is by means of a regulator of the centrifugal force of the regulating shaft. So, synchronization with the electric grid is obtained automatically after a manual starting of the regulator.

The engine and alternator group are controlled automatically and can be shut down remotely in the event of a fault. The whole cogeneration system, inclusive of the heat transfer grid, are regulated and controlled remotely. On-site tests and measurements of the electric energy efficiency showed approximately 18 -19 % at operation time of approximately 3,500 hours per year.

Organization models of wood energy production

Model of management

The use of wood fuel for energy purposes can be implemented through different models of application and/or management of the production cycle. The point is about the organization forms and composition of the persons which carry out a certain business and follow different objectives, and hence are of different technical and economic nature most often defined by special standards and technical regulations.

The subject matter that will be discussed here concerns models of farms, or speaking more generally, farm and forestry enterprises in which the farmer and/or forestry company plays the main role under the form of a sole trader or a limited liability company, and can be described in brief in this manner.

Round heap of logs.

The oldest and most widespread form of use of wood for energy in farm and forestry enterprises was "by own means for own needs". A farm or forestry enterprise would produce wood fuel from the tree and plant species available locally (forest, hedge, formation in middle of field of average life 4-7 years), in a quantity sufficient to meet their own annual energy needs. The typical thing in this case is that the main and exclusive aim is the production of energy for heat both for the work premises (offices, greenhouses, etc.) and the house of the entrepreneur and his relatives.

The main advantages are the savings on an annual basis from previous high expenses for fossil fuel which has shown a trend for high price rise in recent years. Therefore, the sum of the annual savings compared to the previous situation can be considerably high.

The other models of application are as follows:

"Heat for the neighbour" model: can be considered as an alternative to the first model in which the farm or forestry entrepreneur provides the fuel for his residential/business needs (this is the main objective) on his own. In addition to this, he would link his system to the heat system of his neighbours through a small heat transfer installation. Normally, this would be a very short local grid (20-80 m) to avoid excessive connection expenses. He would lend to these neighbours the heat produced from wood chips in his own boiler and this would be measured and invoiced through a special and certified instruments which will be calibrated on an annual basis. The consumer is independent, that is, he can take energy from the primary grid according to his discretion.

A close look at wood chips

The sale of energy will be done in accordance with a contract signed between the parties (for example, a private contract). This contract shall contain at least all provisions under the current legislation plus, of course, a clause which shall determine the price of the energy sold (€/MWh) and price adjustment clauses depending on the price trends in similar services.

Management of local grids and contracts for supply
Supply of wood chips: according to this model the farm or forestry entrepreneur would supply wood fuel (for example, food chips) produced on his site not only for his own heat system, but also to the local market and sign supply contracts with one or more physical and/or legal persons since the entrepreneur has excessive quantities of this fuel.

Production site for wood chips

Consequently, this requires the availability of sites either within the farm or forestry enterprise or outside, that would be suitable and have facilities for storage of the wood chips. The wood fuel would be kept there and prepared by drying for use by all consumers at times of higher demand.

A contract for the supply of wood chips for fuel can be executed in three ways:
- sale by volume (in bulk by cubic metre);
- sale by weight (by tonne);
- sale by energy content (the energy content per unit of weight is determined depending on the water content; this method is to be recommended).

Sale of heat or energy service: in this event, the farm or forestry entrepreneur acting as a sole trader or a limited liability company, would finance and provide technical implementation of a service for a public an/or private consumer. For example, a residential house, the municipal hall building, sports centre, schools. The entrepreneur will sell them the heat energy he has produced at the facilities erected on the consumer's own premises. The operations related to this sale of energy are also carried out under the provisions of a contract executed in accordance with the current legislation and regulations in this field.

This type of business is referred to as "energy service" or "E.S.Co." and is normally provided by companies specializing in the energy sector.

Energy meter for measurement of energy supplied

An E.S.Co's main objective is the achievement of energy savings for the consumer. Part of the money saved per unit of supplied useful energy in the previous fiscal year is allocated between the E.S.Co. and the consumer in the form and manner as set forth in the contract and subject to change during the time of the investment. Change of contact terms are discussed and accepted by both parties.

With the exception of special cases when the entrepreneur is also directly in charge of running the heating system, he would be normally required to employ a person with the relevant technical skills (industrial expert or heating engineer) to run and manage the heat system in accordance with the law.

Supply of heat by farms and forest enterprises

Until the end of 2005 the production and eventual sale of energy by farms and forestry enterprise was considered as a commercial income and therefore was subjected to direct taxation. And direct taxation is much more unfavourable than the tax scheme applied to typical farm activities and the approved related activities.

In the first months of 2006 an important reform in the fiscal legislation of Italy in favour of farm and forestry entrepreneurs was passed. Activities for production and sale/cession of energy, both for heat and electricity now fall within the civil and fiscal scheme of the agricultural income and this is an advantage compared to direct taxation.

Special details of contracting procedure

For the purpose of regulating the activities related to the supply of wood chips and sale of heat, the minimum requirements for the preparation of a contract which has to be signed by the contracting parties are described here in brief.

Contract for supply of wood chips

The items which are of significant importance in the preparation of a contract for the supply of wood chip fuel are delivery **time** and amount of **annual needs** of wood fuel and possible deviation in the form of excess or deficiency due to seasonal conditions.

It is also important to specify the **origin of the biomass** in accordance with the local current regulations on use of wood fuel for energy.

A heap of wood chips

Another item of importance which has to be defined is the **size of the chips**. This applies especially to small and medium heat systems which require chips of homogenous sizes for a normal and accurate running of the automatic feeding screw conveyor of the combustion chamber. In addition, it is better to specify the parameters of the purity or the limit requirements for the presence of admixtures in the fuel charge such as wire, nails and other metals.

The measurement of water content of fuel is of significant importance in the determination of the price of the supplied fuel.

A device for measurement of water content of wood chips

In practice, this can be quickly done with samples from the supplied wood fuel taken by the operator in charge of the heat system.

The price of the fuel supplied is determined with the help of the table below on the basis of the total weight simply measured by weighing and the average water content. As can be seen from the table, the drier the chips are, the higher their price will be. The wetter the fuel is, the lesser its useful energy will be, but the price of the useful energy of the fuel will remain the same (for example, €/MWh 16.10).

Price of wood chips depending on water content

MJ/t	MWh/t	w (%)	€/t		€/MWh
14312,00	3,98	20	€	64,06	16,10
14102,60	3,92	21	€	63,12	16,10
13893,20	3,86	22	€	62,18	16,10
13683,80	3,80	23	€	61,25	16,10
13474,40	3,75	24	€	60,31	16,10
13265,00	3,69	25	€	59,37	16,10
13055,60	3,63	26	€	58,44	16,10
12846,20	3,57	27	€	57,50	16,10
12636,80	3,51	28	€	56,56	16,10
12427,40	3,45	29	€	55,62	16,10
12218,00	3,40	30	€	54,69	16,10
12008,60	3,34	31	€	53,75	16,10
11799,20	3,28	32	€	52,81	16,10
11589,80	3,22	33	€	51,87	16,10
11380,40	3,16	34	€	50,94	16,10
11171,00	3,11	35	**€**	**50,00**	**16,10**
10961,60	3,05	36	€	49,06	16,10
10752,20	2,99	37	€	48,13	16,10
10542,80	2,93	38	€	47,19	16,10
10333,40	2,87	39	€	46,25	16,10
10124,00	2,81	40	€	45,31	16,10
9914,60	2,76	41	€	44,38	16,10
9705,20	2,70	42	€	43,44	16,10
9495,80	2,64	43	€	42,50	16,10
9286,40	2,58	44	€	41,56	16,10
9077,00	2,52	45	€	40,63	16,10
8867,60	2,47	46	€	39,69	16,10
8658,20	2,41	47	€	38,75	16,10
8448,80	2,35	48	€	37,82	16,10
8239,40	2,29	49	€	36,88	16,10
8030,00	2,23	50	€	35,94	16,10

The price of wood chips given in the above Table is only for information. The two parties, buyer and supplier, can negotiate different prices that can be lower or higher than in this example.

And also, it will be good to provide for the terms of price adjustment of the wood chips in accordance with price escalation or as a percentage of the price fluctuation of fossil fuels used as the equivalent fuel.

Items contained in a contract for energy service

The typical items in a contract for sale of heat energy are as follows:

- Legal provisions about scope and duties related to the heat service;
- Identity details of contracting parties;
- Purpose and subject of the contract;
- Duration and renewal of contract;
- Supplier's responsibilities (production of energy for heat and sanitation water, heat metering, invoicing, management and maintenance);
- Metering and charging of energy supplied (instruments and their calibration);
- Price of energy supplied; price re-negotiation and escalation;
- Checks and measurements of instruments;
- Instalment payments and accounts adjustment;
- Consumer's responsibilities;
- Fuel: type and quality;
- Routine maintenance (cleaning, functional tests, replacement);
- Extra maintenance;
- Check of temperature in the rooms receiving the service;
- Insurances
- Settlement of disputes.

Economic Evaluation

Profitability of farm and forestry products

The factors of profitability are closely related and are dependent on the type of the model followed and also the particular situation involving mainly the type of technology and the fuel previously used.

The extent of profitability involves directly the entrepreneur and it is possible to distinguish mainly the following two types:

- the one who sells wood chips to one or more buyers under contract for shorter or longer period of time;
- the one who sells energy by investing his own capital and in fact, through the sale of heat performs a service.

The use of wood fuel for energy applications in the case of a production process intended to meet the own needs, as already mentioned, can lead to "saved expenses" and therefore to profit, if compared to the average expenses in the previous years during which the trend to a rise in prices has been rather well expressed, especially in most recent years and even in the agricultural sector where the price regime (at least for Italy) is relieved (for example, heating of greenhouses).

In addition, persons from the farm and forestry sectors producing wood fuel in quantities exceeding the needs of their own business, have the opportunity to sell one such product as wood chips in the local market. This means an increase of the value of this secondary product for which no evaluation was possible at an earlier phase and, therefore, it is a form of diversification/integration of the own income.

In general, persons from the farm and forestry sectors producing timber can also produce wood chips and be interested in this business.

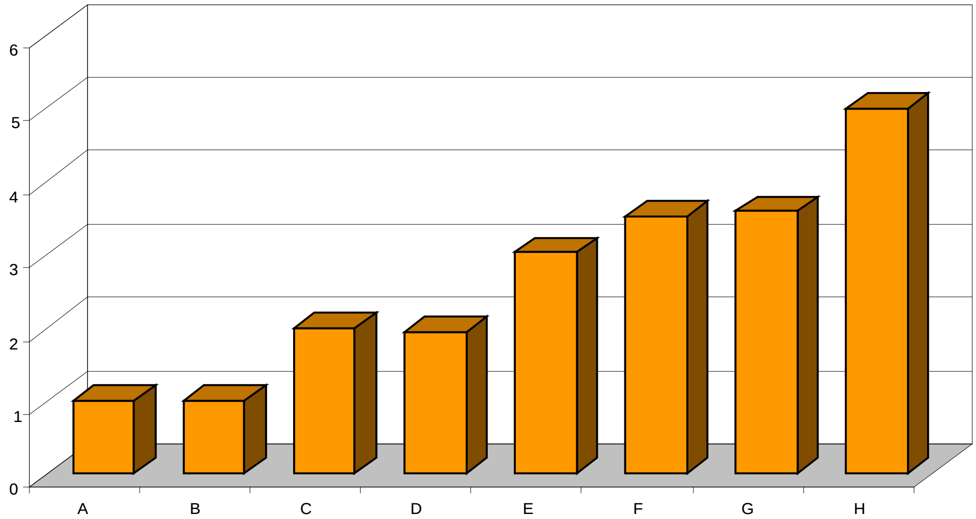
Comparison of energy prices from different fuels

The first parameter required for an accurate assessment of

Price of energy from different forms of wood fuel and from two fossil fuels

			Price		Factor	VAT
		MWh	€	€/MWh		
A	t wood chips (30%)	3,4	60	17,65	1,00	10%
B	t wood chips (40%)	2,81	50	17,79	1,00	10%
C	t whole wood (25%)	3,69	130	35,23	2,00	10%
D	t pellets (8%) in bulk	4,7	160	34,04	1,93	20%
E	t pellets (8%) in bags 15 kg	4,7	250	53,19	3,01	20%
F	100 m3 methane	1	62	62,00	3,51	20%
G	1000 litres of gas oil for agricultural applications (ex store)	10,7	675	63,08	3,57	20%
H	1000 litres of gas oil for heat	10,7	941	87,94	4,98	20%

NOTE: Average prices for April 2006, net of VAT. VAT is shown separately in right-side column.



Graphical representation of the above table

an investment is the determination of the comparison price of the alternative energy fuels. This is the price per unit of energy that can be obtained from the fuel, that is, the average production price per unit of energy – the heat MWh supplied.

Under €/MWh here is understood the gross price, that is, the thermodynamic efficiency of the boiler system is rather not considered at this stage.

In terms of energy (supplied MWh), the various fuels shown below have the characteristics as obtained from internationally approved data.

Naturally, the variable value is the price per unit of a certain fuel and it is dependent mainly on the market used as the reference point and the economic situation worldwide. As about heat wood and wood chips, the price is closely related to the change in local demand and supply.

The sale of wood chips with certain energy content is illustrated here and that is why one and the same value for the price factor of wood chips with different water content is shown.

As can be seen, the price of energy contained in different wood fuels is quite different. It can be said, taking into account the price conditions defined here, that the production of heat energy through the use of agricultural gas oil as compared, for example, with wood chips, is 3.57 times more expensive.

It is evident that in this type of calculations no account is taken of the initial capital or investment. This aspect will be discussed in the following chapters.

Price of heat system and return on investment

At the present, the cost of a heat system (boiler plus accessories) running on wood fuel for production of heat energy is higher, and even significantly, as compared to boilers running on fossil fuels.The price of a heat system is dependent mainly on the following items:

- type of boiler (travelling or inclined grate);
- boiler rating;
- feed system;
- length of the heat transfer system;

Who can make wood and wood energy cost effective?

Each tonne of wood chips (of water content 30 %) produces about 3 MWh heat energy taking into account thermodynamic losses in the system.

A market price of about € 60 plus VAT per tonne can be assumed for the wood chips.

In the event a farmer sells heat energy, one tonne of wood chips can produce, as stated above, about 3 MWh.

The price of heat energy varies in the range of € 70-90 per delivered MWh. So, an average price of € 80 per MWh can be assumed.

If heat energy contained in wood is sold each tonne of wood chips will give 3 MWh x €80 /MWh = € 240.

These figures have to be compared with the € 60 which a farm or forestry entrepreneur would receive from the sale of the wood chips.

Obviously, what remains is to make assessment of the financial "sustainability" of an investment in a heat system (boiler and accessories) which a farm or forestry entrepreneur should make to be able to supply heat energy to the consumer.

- number of substations;
- construction and additional works.

The following methods have to be used to enable the inclusion of the amount of the invested capital, as well as all required expenses in the calculation of the energy produced:

It is recommended to make calculations both with and without a subsidy.

B and C) Expenses incurred (plus VAT, if this is an expense for the entrepreneur), as well expenses for design, safety and contingency. It is good to have both figures – with or without a subsidy granted.

D) Normally, one value covering a period of 15 – 20 years is used dependent on the type of the heat system and manufacturer's instructions.

E) It is used to distribute the initial expense over the years, in equipment of long payback time, purchase of the boiler and its commissioning. Share of the payback is the financial capital which has to be put aside every year so that it will be possible to have the initial capital at the end of the technical and economic period. It is determined as a percentage in the range of 2-3 % and is calculated from the following formula:

G) Is the average annual consumption of fuel maintained at least during the last three years.

H) Is the average annual expense for purchase of fuel maintained during the last three years.

G) Average annual assessment of electric energy consumption for running of the boiler. It can be calculated from the rating of the installed electric motor, number of running hours and extent of running of the motors compared to their maximum rating.

L) Calculated on the basis of the cost of labour for maintenance, adding expenses for eventual replacement of parts carried out within one year.

M) Is the result of the sum of the following items: E + H + I + L, expressed in €:

N) Is the result of the sum of the following items: F + H + I + L, expressed in €;

O) Is the value to be finally determined. It is obtained by dividing the value of M by A, expressed in €/MWh. The same applies to line P, where the value of line N is divided by line A.

The value €/MWh is the available energy after the boiler, and not the actual energy measured by the consumer's meter.

Calculations with and without a subsidy are required to

Heating on fossil fuels:

A	USEFUL HEAT ENERGY SUPPLIED PER YEAR	MWht
B	INVESTED CAPITAL (net of subsidy)	€
C	INVESTED CAPITAL (plus subsidy)	€
D	DURATION OF INVESTMENT	years
E	SHARE OF FINANCIAL RETURN ON CAPITAL (net of subsidy)	€/year
F	SHARE OF FINANCIAL RETURN ON CAPITAL (plus subsidy)	€/ year
G	ANNUAL CONSUMPTION OF FUEL	l/ year
H	ANNUAL EXPENSES FOR FUEL (unified price €/m3 or litre)	
I	ELECTRIC ENERGY	€/ year
L	ROUTINE/EMERGENCY MAINTENANCE, MANAGEMENT AND SUPERVISION	€/ year
M	AVERAGE INVESTMENT PER YEAR (net of subsidy)	
N	AVERAGE INVESTMENT PER YEAR (plus subsidy)	
O	ANNUAL PRICE of supplied MWh (net of subsidy)	€/MWh
P	ANNUAL PRICE of supplied MWh (plus subsidy)	€/MWh

Share of payback = C0 x p/sn-1

know how such subsidy will affect the final price of the energy. This is especially useful in cases when offering of energy service is being planned.

Heating on wood fuels:

The only difference in the wood fuels compared with the previous Table is the item related to the annual cost of ash disposal, with the exception of cases of eventual re-use of ash for which some industries are even ready to pay and make it a source of income, not expense. In any case, it should be included in the calculation of the cost per unit of energy produced.

Assesment of investment

An assessment of the investment is made to monitor the effect a certain investment project will have on its implementing structure (enterprise, public organization, private organization, etc.). Under an investment project is understood a complex of activities related both to production and financing in which an organization or individual physical person is participating with available cash (cost of investment) with the purpose of obtaining a flow of future profit of a total amount higher than the incurred expenses.

The problem we are faced when assessing an investment is in fact a problem of choice. Any physical or legal person has to take decisions on investment aimed at directing the limited available resources only toward value creating projects.

To solve one such problem and make the choice among several possible alternatives it will be necessary to find the difference between them on the basis of a "leading criterion" which will be suitable to show both the viability of the initiative and the relevant economic and financial effects. It is generally accepted that the main leading criterion applied in such case is the financial value at the time of the initiative. And all the more that the opportunity to finance the initiative is related to loans from financial institutions (banks, foundations) or a flow of capital which cannot be directly oriented toward the person proposing the investment.

In addition, assessment of a certain investment requires a comparison with one or more alternative situations among which the existing system in the event of placing a new biomass system, taking into account the data described above or the production cost of the heat supplied in MWh.

The method recommended to make an accurate analysis is this of the Cost-Benefit Analysis (CBA) which involves the following phases:

- formation of a **cash flow** to find out whether or not the investment, for example, in a new asset, is worth making through calculation of the present value of cash flows involved in the investment project by applying a discounting rate (2–8 %). The algebraic sum of the present income and expenditure at the present time or at the time of taking a decision on investment represents the net present value (NPV) of the project, if NPV is positive

- **internal rate of return** (IRR): calculation at what rate of interest the total discounted annual amounts of income would be equal to the capital sum needed to buy the asset at the present. If this rate of interest, or yield, is greater than the market rate, the investment may be regarded as profitable.

- **Payback time:** calculation of number of years required for return on the initial investment through the expected cash flows it generates with time.

Study cases

Three examples of practical applications and relevant economic assessment of the investment

1) Woodlog boilerAgriturismo LIVIERI

The boiler has a heat output of 55 kW. This is a reverse combustion boiler with manual feeding of wood fuel. The heat station provides both heat and warm water for sanitary needs. The system has heat accumulation (2 tanks) for water of total volume 3,500 litres plus a water heater of 400 litres for sanitation needs.

Farm Holiday Cottages

Each charge takes about 60 kg of naturally dried wood logs of water content 20-25 %. Complete combustion of one full charge lasts 4 to 5 hours and has to be continuous until its full completion. During this period the heat energy produced is almost always more than needed and that is why it is stored in the heat accumulators (80-90°C) to be available for use in the following few hours and to avoid new starting of the boiler. Because of this, it is a legal requirement to have suitably sized accumulators installed at boilers running on wood.

Feeding phase for the boiler fired on wood.

After several years of operation we have collected some main performance data necessary to make an assessment of the investment as shown in the Table below.

COST OF INVESTMENT (net of VAT)		
TOTAL INVESTMENT (net of VAT)	Euro	€17,916.67
SUBSIDY, percent	%	70%
SUBSIDY, cash	Euro	€12,541.67

OPERATING COSTS		
COST OF WOOD (own production)	Euro/ tonne	65.0
COST OF WOOD (purchased)	Euro/ tonne	120.0
ELECTRICITY COSTS	Euro/year	150.8

OPERATING COSTS (Manpower)		
ROUTINE MAINTENANCE + TIME FOR CHARGING	Euro/year	550
EMERGENCY MAITENANCE	Euro/year	40
CLEANING OF FLUE STACK	Euro/year	60

Heat accumulators

INVESTMENT B) Economic data for boiler on methane (no project available)

The developing countryside tourism should in any case take the necessary steps and install a heat system in the place under consideration. The point is about a boiler on methane, of the same output, at a total cost of € 3,000 (boiler frame, piping and test run). In addition, for the purpose of determination of the average annual consumption it has been calculated that the boiler would supply annually the same net heat energy as this produced from a boiler on wood (standard heat needs). These results were used to draw a conclusion on the annual consumption of methane in cubic metre and the related costs.

COST OF INVESTMENT (net of VAT)		
TOTAL INVESTMENT	Euro	€ 3,000.00

OPERATING COST		
COST OF FUEL	Euro/tonne	€4,950.00
MAINTENANCE COSTS: ROUTINE AND CURATIVE	Euro/tonne	€ 180.00

As the wood logs used are of identical or at least comparable water content in %, it would be useful to make the following initial division in view of assessing the investment:

- Own production of the necessary wood to cover the annual heat needs, the cost of which is determined at € 65/t;
- Purchase of wood from the market at the cost of € 120/t.

For the purpose of preparing a more detailed assessment of the investment, also the most suitable level of subsidy should be looked for in each of the above two alternatives.

For this purpose, several different possible hypotheses are considered outside the one to which the consumer has a real

access:
- lack of subsidy;
- subsidy of 30%;
- subsidy of 70% (the real case).

To simplify this case, a tentative reduction of 5 % is assumed for each of these alternatives.

The negative NPV shown in the red columns shows that the investment is not profitable, but with time NPV turns into a positive value - the green columns show the situation under which the profit will exceed the initial investment cost.

2) Small boiler system on wood chips for A. CALZAVARA
("heat for the neighbour" model)

This is a case in which the farm entrepreneur decides to install a boiler run on wood chips to supply heat for his house, relatives and neighbour. He is selling energy to his neighbour under contract through a small heat transfer system.

Year of implementation	2005
Boiler output (kW)	45
Heated volume (m3)	1,562
Number of people	8
Number of heated buildings	3
Length of heat transfer system (m)	120
Number of work hours per year	2,150
Supplied heat energy (MWh/year)	96.8
Heat energy for own needs (MWh/ year)	80.0
Heat energy sold (MWh/ year)	16.8
Price of sold energy (€/MWh)	40
Electric energy used (kWe)	0.95
Annual fuel consumption (t)	32.5
Water content in fuel (%)	30
Price of wood chips own production (€/t)	54.7
INVESTMENT A – Boiler on wood chips	
Cost of boiler on wood chips(€)	17,000
Construction works (€)	1,000
Cost of distribution piping (€)	5,500
Cost of transfer system and accessories(€)	4,700
Annual deduction IRPEF for 10 years (€/year)	622.80
TOTAL INVESTMENT(€) - (net of VAT)	28,200
Subsidy(€)	10,900
Current maintenance (€/year)	140
Emergency maintenance (€/year)	120
Annual discounting rate (%)	5
INVESTMENT B – Boiler on methane	
Investment for boiler on methane (€)	2,000
Annual savings from methane (€/year)	4,800
Annual maintenance (€/year)	260

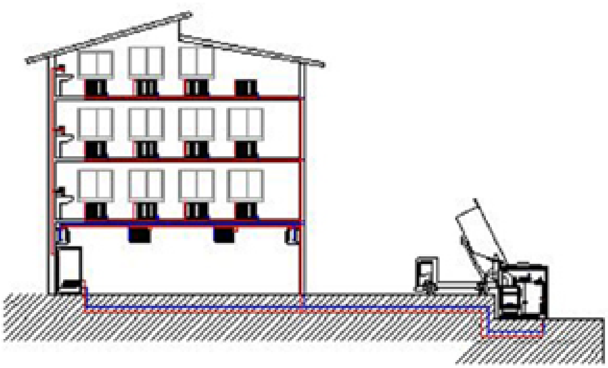
3) Sale of heat: activities of ECODOLOMITI srl

The heat system is purchased, installed and managed by the farm/forestry entrepreneur. In this way the entrepreneur is not limited only to the delivery of the wood chips, but also sells energy directly to consumers with the purpose of increasing his profit from the business. In addition, this model of the production process contributes to the solution of many of the supply related problems, and more particularly, energy characteristics of fuel and its price.

There is a great possibility at least with small and medium heat systems that the person operating the installation is the supplier of the wood chips at the same time:

- this makes the whole difference in benefitting from the production of fuel of high quality and high energy content that will ensure optimal running for the heat system,
- the cost of wood chips is determined in accordance with the profit from the sale of energy and because of this the useof forest plants proves suitable even when "macchiatico" (a technical term referring to the cost of trees not cut down) is negative as:
- wood chips is a product obtained from improvement cutting of local forests and the production process affects positively the area and community in terms of environment and labour employment.

In 2003 a farm in Agordo, (BL), Italy set up an energy service company (E.S.Co) and installed a heat station 90 kWt for the offices and stores of a local private company. The station consists of a mobile boiler and an existing gas oil boiler.



The latter will be operated as a stand-by boiler in the event of emergency. Wood chips are produced by the farm and sold to the local private company under an energy supply contract.

The financial performance of the station has been monitored since its commissioning in conjunction with the owner and operator.

The most essential performance data are given in Table 1. The method used for assessment of the investment foresees a 17-year operational life time of the station. The cash flows of income (sale of energy) and expenditure (investment, fuel price, maintenance) are shown in detail by months. Information for the first two years has been obtained from the station manager and forecasts made for the other years. Annual differences between profit and costs are given at their present values (net present value – NPV) applying a 5 % discounting rate.

The accurate distribution of profit and costs over a certain period (17 years) allows comparing cash flows created during different periods of time and making an analysis of the sensitivity points of the main variables and also checking the alternatives.

With the establishment of E.S.Co two main objectives have to be taken into consideration, the implementation of which can seem contradictory:

- to ensure energy savings to the consumer through the use of most advanced technology (system efficiency);
- to ensure adequate return on investment to the E.S.Co through a variable portion from the savings achieved.

It is considered that the company manager would be able to obtain a payback for the wood chips at € 20-22/m3 which is € 80-88 per tonne at water content of 35 %.

Development of the Investment with time

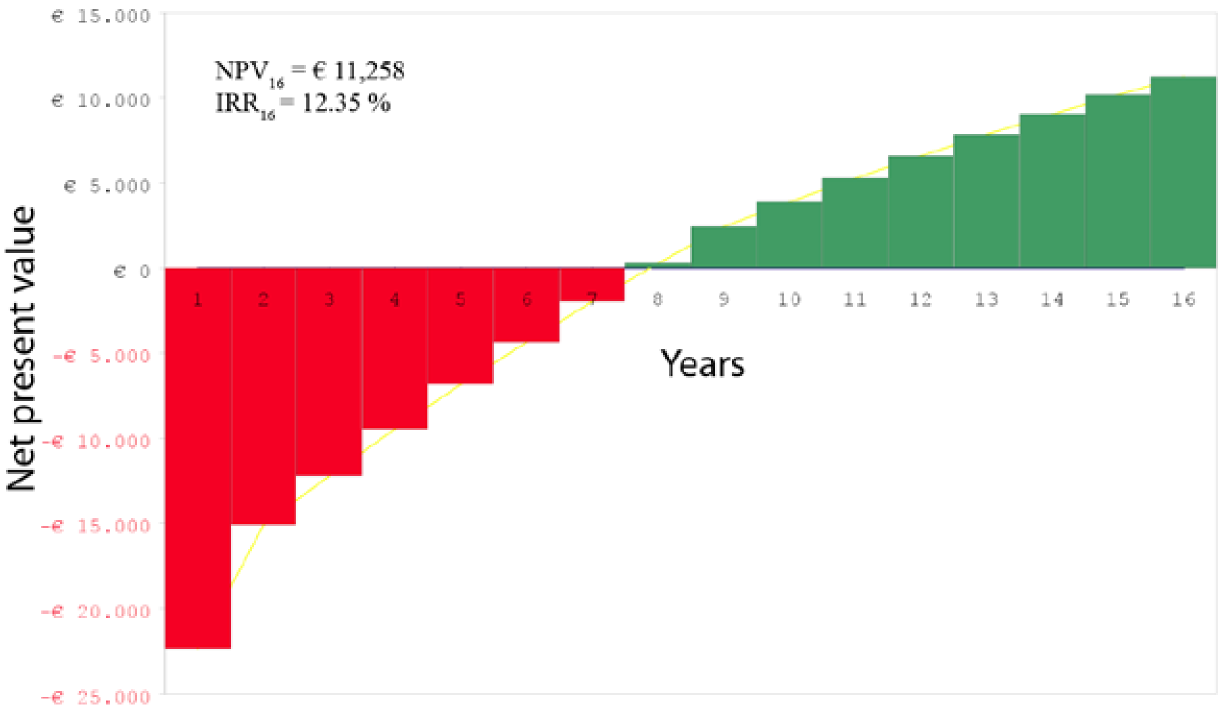
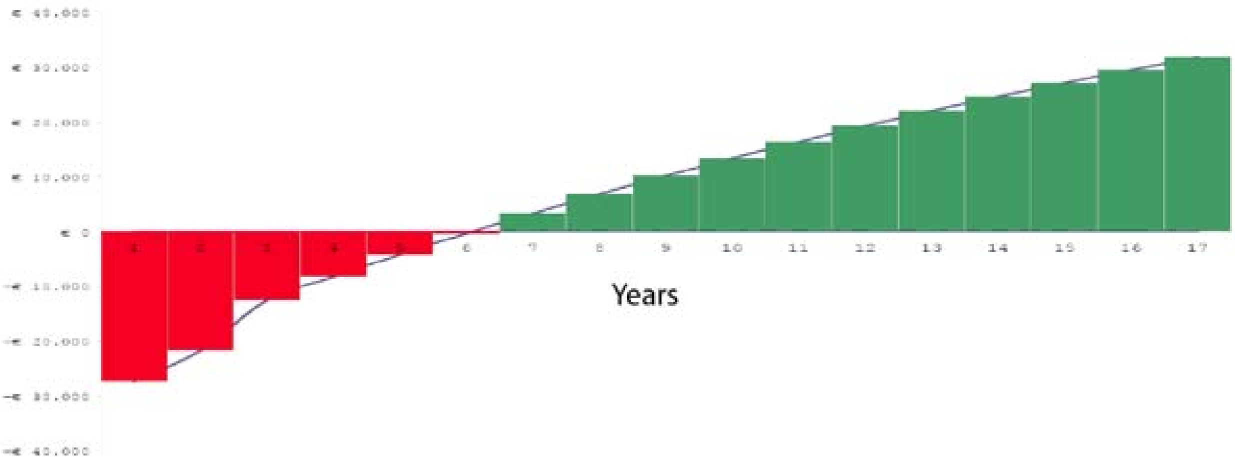


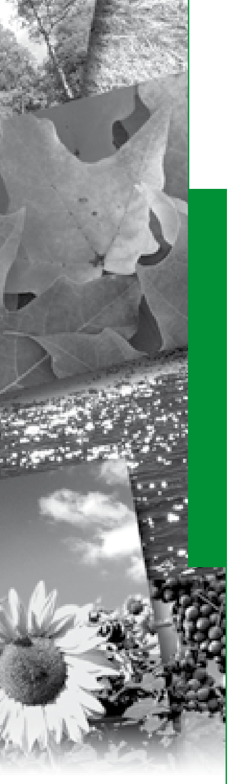
Table 1 – Technical and economic data

EXPENDITURE		
Initial investment (October 2003)		€ 30,000 (net of VAT)
Subsidy		none
Heat system		€ 2,000
Annual maintenance		€ 600
-	routine	€ 480
-	emergency	€ 120
Production cost of wood chips (25-30 % water content)		30 €/t
November 2003 – April 2004		45 t
September 2004 – April 2005		70 t
PROFIT		
COST OF ENERGY		
- November 2003 – April 2004		70.00 €/MWh
- September 2004 – April 2005		72.16 €/MWh
ENERGY SOLD		
- November 2003 – April 2004		97.4 MWh
- September 2004 – April 2005		115.6 MWh



Summary of financial parameters:

NVP (after 10 years): 13.300 €	IRR: (after 10 years): 14 %
NVP (after 17 years): 31.700 €	IRR: (after 17 years): 18 %



HERBACEOUS BIOMASS AND ITS ENERGY USES

Introduction

New trends in the European Agricultural Policy and prospects of biomass crop development

The crops cultivated as biomass for energy use present a huge interest, as they provide a possibility for achieving a positive energy balance in the process of agricultural production. This is a serious precondition for their recognition.

Two big families can be pointed out among the crops cultivated for biomass:

- fast-growing woody and cellulose crops, (for instance poplar, acacia, willow, eucalyptus, etc.), as well as perennial species, grown in the "Short Rotation Forestry" (SRF) methods, mainly intended for wood;
- grasses, annual or perennial, cultivated for production of energy feedstock in the form of dry matter or grain (for example corn).

In terms of energy the feedstock, derived from SRF is fully analogous to that of forestry biomass (see the section examining the above). The current chapter studies mainly grasses. In analyzing the potential of grasses we have to consider the fact that their use for energy purposes rivals their use for food.

Apart from grasses cultivated for energy, energy biomass can be derived also from crop residues, grown for other purposes. In this case the residues are in the form of straw (for example wheat) or culms (for example corn, sunflower).

The latest trends in the Agricultural Policy of the European Union are a precondition for choosing energy crops, cultivated for biomass, since their economic significance is not less than that of ordinary plants. The reform of the European Agricultural Policy introduces a series of new measures, directed mainly at reorienting of productions with regard to the market. By the separation criterion, introduced through the reform of the European Agricultural Policy, the agriculturalist shall receive grants, irrespective of the species and use of the crops, cultivated on the farm. Thus he is no longer restrained in his choice (by way of receiving premiums in different amounts according to the crop species), but is free to cultivate what is more profitable on the market at the moment.

This particular aspect undoubtedly plays an important role to the advantage of food crops, inclusive of the energy ones. In fact they are equipollent to any food crop, to differ from the past, when non-food crops were grown in the peripheral low-production areas, usually defined as set aside. Apart from that the new Agricultural Policy provides an extra premium of 45 Euro/hectare for energy crops cultivated for the production chain of biofuels and energy biomass. The aid is limited to the maximum plan area of 1,500,000 hectares for the entire usable farmland (SAU) of the European Union. The subsidies shall be granted only for areas, agreed between agriculturalists and processing companies, save for the cases when the agriculturalist himself carries out the processing within his own farm. Not later than five years after the Regime of energy crops has started, the Commission shall present before the Council a report on its status along with possible proposals.

The energy biomass can use also national grants, covering up to 50% of the costs related to planting perennial crops in uncultivated lands. Moreover, in the period 2007-2013 producers of energy crops can receive grants to specific amounts for development of rural regions, provided for in Regulation CE No. 1698/2005 and financed by the European Fund for Development of Rural Regions (FEASR). It is very likely that the new Schemes for Development of rural regions for EU countries include specific measures for promoting non-food crops, as well as developing local agricultural and energy productions.

1.The data and conclusions given in this chapter for the major part are the result of two projects, presented by the Agency for scientific research, developments and innovations in agriculture in Tuscany region: "ACTIVA (2004-2005)" Project related to scenarios for development of non-food crops, coordinated by the authors off this chapter, and "BIOENERGY FARM" Project presenting the crops cultivated for energy use. Head of the scientific research of departments related to crops cultivated for energy use for both projects is Professor Enrico Bonari from the high-level institution St.Anna in Pisa

Grass crops and development of rural regions

The close interrelation between the quality of agrarian farms and the quality of the land they cultivate is widely recognized. In this respect the quality of land means the development of one model of growth, which satisfies the requirements not only for agrarian farms but also for the farmland as a whole, in conjunction with services for the population, the infrastructure and other economic activities, different from agricultural ones. This context includes activities, directed toward the introduction of renewable energies in agriculture. The guidelines of the new Agricultural Policy have finally adopted the concept of promoting development of rural regions in general and not only within the separate agricultural farms.

The local production of thermal or heat-and-power energy from crops cultivated to this purpose can bring about significant benefits not only to the agricultural farm but also to the entire vicinity. It will boost the propagation of energy crops and the local energy self-sufficiency, will mitigate the climatic conditions, and create new favourable job options and income through the developing of integrated energy chains.

Most grasses studied hereby, remarkable for their high yield and simple cultivation, require little watering and fertilizing. This makes them especially interesting not only for their contribution to ameliorating the climatic conditions but also for improving the quality of soils and reducing ground water contamination hazard.

The fact that the energy use of agricultural crops or crop residues is related to centuries old traditions in rural areas should not be ignored. In many regions traditional species in the past such as the giant reed, sorghum or grain crops, which during the last decades were not of any economic interest, can again be included in crop-rotation. The role of energy crops has been categorically recognized under the new EU Regulation 1698/05 for development of rural regions, approved on 20th September 2005. The Regulation ranks among the strategic goals "assessment of environment and nature and support of territorial management (Clause 5)". Among the key principles for management of rural territories, the Document numbers "the reduction in climatic changes, particularly reduction in harmful emissions and the greenhouse effect…"; European investment grants aim at "modernizing rural farms and increasing their economic profitability by way of more competent application of production factors; diversification of crops and production in and outside the farm, inclusive of crops belonging to the non-food sector, including energy crops..." (item 21 from the Introduction).

Similarly the European Regulation recommends that "improvements in the field of processing and selling agricultural and forestry products" are stimulated by means of grants "in order to increase the efficiency of these sectors, to promote renewable energy from agricultural and forestry biomass…" (i.23). The new lines of the European Union for promoting and developing rural regions create preconditions for stimulating the development of the new agricultural and energy chains on various territories.

In this respect the new regulation provides better opportunities also for initiatives on local level, by encouraging cooperation between agriculturalists and the processing industry, especially with regard to renewability of products and processes and the use of new technologies.

Grasses and environmental impact

As noted in the beginning, the main contribution of energy crops is closely related to the tolerance criterion. In terms of tolerance, the characteristic a "renewable" energy source is positive put not sufficient. It is necessary that the energy balance of the entire production process is positive or at least has a smaller environmental impact than conventional sources.

Possible influences on environment, resulting from the treatment processes of energy crops, are numerous and should be assessed in terms of both global energy and climate (emissions in atmosphere, climatic changes, biologic variety ...) as well as in terms of agriculture and territory (impact on soil, water, landscape…).

Apart from yielding production of economic significance, biomass crops contribute to the reduction in harmful emissions dissipated in the atmosphere; their propagation has a positive effect on environment; owing to them uncultivated agricultural lands will be put to a useful purpose. Their use for energy, instead of traditional fossil fuels, and for agricultural purposes, instead of traditional commercial crops, has had the following environmental impact:

- **Reducing CO_2 emissions** In respect of emissions the effect from the use of grasses for energy purposes is entirely analogous to that which is generally observed for all biomass crops. Like all plants during photosynthesis they absorb CO_2 from the atmosphere and release it during respiration and decomposition of residues, more precisely – during their burning. As a whole the absorption and release are balanced, although there are certain deviations depending on the duration of the cultivation and production cycle. Another specific advantage of perennial grasses to traditional annual crops is the smaller amount of emissions during the preparation of soils, because it is done less frequently.

- **Increasing the organic carbon in the soil (Carbon Sink)**. Another positive effect is the improved balance of organic carbon in the soil, which is an extremely important indicator for its fertility. It is seen from the available, but still scarce literature on the matter, that the crops cultivated for energy and planted on areas where traditional food crops were previously cultivated (for example corn, sunflower, etc), can increase the amount of carbon in the soil up to 40-50 tons per hectare over a period of 20-50 years.

- **"Possible" increase of biological variety.** A reliable assessment of the impact which one annual energy crop has on the biological variety compared to a traditional grass crop requires profound research. It could be noted, however, that biomass crops are not treated with herbicides typical of food crops, because their end use allows greater tolerance to weeds and consequently, enriches the entire agro-ecosystem (in fact weeds are the habitat of insects and parasites, and are also palatable food for different herbivores). Even in this respect the effect is bigger with perennial species.

- **Positive energy balance.** Another ecological indicator of particular importance is the energy balance or the ratio between the total energy, obtained as output biomass and the total non-renewable energy, consumed for obtaining this product. (input biomass). A complex assessment should be made with regard to the fertilizers used in the overall production cycle, plant protection agents, mechanic haulage and transport, during the production cycle. The high level institution St.Anna has carried out long-time experiments in the valley around Pisa with some grass species (sorghum, miscanthus, giant reed) and SRF of poplar, cultivated for input energy with high and low level. The results given in table 3.1 show assessments related to energy balance, both in respect of the absolute quantity of energy, produced from a unit area, and the more or less increased yields from the additional energy, put into the different plants. The data regarding crops of giant reed and miscanthus as well as the assessments relating to SRF of poplar and the crops with a lower level of input energy are of particular interest.

- **The reduction in the use of plant protection agents and fertilizers and consequently reducing ground water contamination hazard.** This statement is apparently true in the rather frequent cases, when instead of the traditional agricultural crops, requiring greater quantity of fertilizers and plant protection agents, energy crops are planted.
- **Increasing organic matter in soil.** This effect is encountered mostly with densely planted grass perennial crops (as well as with woody species SRF), because it reduces the risk of erosion in sloping sections, as well as in the particularly sensitive flat terrains. This result is due to the combination of numerous factors: 'covering' of soil, as a result from the nearly perpetual vegetation cover and the increase of organic matter in the covering soil layers; the 'fertilization' effect from the leaves falling throughout the year and the effect from holding soil, due to the roots of the plants. The increase of organic matter in soils is a very important factor, in the case of annual arable crops, excessively used pastures or uncultivated land in a very poor condition.

In view of improving the environment the role which the different crops cultivated for production of biomass can play effectively for conserving certain special zones (shelter belts along water courses and streams, reducing erosion risks, water catchment areas for plant treatment, etc.) should be seriously taken into consideration. And, finally, the possibility for utilizing the ash from energy crops in agriculture should not be disregarded.

What should also be taken into consideration are the problems of the landscape which inevitably can arise when these crops are introduced in rotation, especially in agricultural regions whose landscape features were characteristic and usual for inhabitants and visitors.

As for wastes from crops cultivated for other purposes, generally the same conclusions for the environment apply, as for crops cultivated for energy, but the problem arises whether their complete removal from the soil is pertinent. The carbon content in residual agricultural biomass is of essential importance for the fertility of the soil. In order to maintain fertility is it recommended that part of these residues is left on the surface or buried in the ground. Unfortunately, it is not always easy to determine the critical level of carbon content, under which the fertility of the soil is irreparably damaged.

Table 3.1 Energy balance of grasses and of SRF of poplar (S.Piero a Grado – Pisa)

	Sorghum	Miscanthus	Reed	SRF A	SRF B
Total input energy	33.0	18.6	17.9	16.3	11.1
Total output energy	491.4	257.0	616.2	415.2	323.5
Output/Input energy	14.9	13.8	34.4	25.5	29.3
Output - Input energy	458.4	238.4	598.3	399.0	312.4
Energy yield Kg GJ-1	930.3	1511.5	2087.8	1356.7	1556.1

Source: Bonari et al – Crops, cultivated for energy use: Bioenergy farm project 2005

ENVIRONMENTAL IMPACT OF GRASSES Cultivated FOR ENERGY OF BIOMASS

NET DECREASE OF GREENHOUSE EMISSIONS
POSITIVE ENERGY BALANCE
REDUCTION IN plant protection AGENTS
CONTROL ON EROSION PROCESSES (perennial species)
IMPROVING the LIVING CONDITIONS OF WILDLIFE FAUNa (perennial species)
INCREASE OF ORGANIC CARBON IN SOIL
REDUCING CONTAMINATION OF RIVERS AND GROUND WATER.

Subjects along the chain

In formulating the projects for energy utilization of biomass on territorial level, which requires activating a chain of different subjects, it would be good to do a preliminary analysis of the available crop species. Agricultural areas are a source of different types of biomass and it is often wrong to accentuate on a single type of biomass. Each local project should be individual, in order to preserve the characteristics of the territory and traditional agricultural and forestry activities, by optimally combining them with biomass sources. When energy grasses are cultivated, as well as when the main producer of biomass is an agricultural farm, the possibility for utilization of residues from pruning or other cultivations should not be disregarded. This will make the activation of the chain more profitable in terms of both economy and energy. The end links of the chain, based on grasses cultivated for energy, entirely correspond to those of woody and cellulose biomass, obtained from agricultural and forestry residues of SRF, from wood-processing residue, as well as from pruning of trees and shrubs in populated areas.

- **Producer: agricultural farm** – in this case biomass is obtained from the activity of the agriculturalist, who may have a triple role in the energy chain:
  - supplier of feedstock,
  - producer (individual or associated) of energy for own use,
  - supplier (individual or associated) of energy on the market.

In the second and third case the agriculturalist is a supplier of energy, and hence should acquire the necessary equipment, enter into contracts for establishing the so called "energy zone" and become manager of a heat supplying plant facilities. Of course, as a supplier of energy, he shall receive a considerably higher added value.

In recent years the Italian government has acknowledged the right of the agricultural farm to supply its own energy, without having to change its legal statute. It should be taken into consideration that apart from biomass derived from purpose grown crops, agricultural activity often is a source of biomass, obtained from residues of other crops (straw from cereal plants, etc.), as well as from pruning of trees. The creation of a local energy chain is more profitable from an economic point of view, if all sources of agricultural biomass are used.

- (Optional) **Processing Contractor – producer of pellets.** Grass biomass, suitably dried, can be burnt as it is. In this case the farmer can deliver the product directly to the system. Due to the characteristics of this fuel (high silicon content in ash, heterogeneity, etc) often it is more appropriate for grass and woody biomass to be mixed in the pelletisation process. Pelletisation provides excellent fuel with homogenous characteristics, but increases considerably the value of combustible feedstock.
- **Consumer.** The primary consumer can be ranked among:
  - private or public consumers, equipped with boilers for heating houses or offices;
  - farms, producing heat for own needs. The consumer may be the same farm or a union of farms using heat for green-houses, drying facilities or other working facilities;
  - power plants or cogeneration plants (heat-and-power plants)

Biomass Grasses

Main biomass crops and debris from cultivation

Most of all the difference between crops cultivated for energy production and those whose debris can be used for energy production should be clarified. Crops for production of biomass for energy use should have maximum dry matter content per unit area, although of a low value. In the late 90s the potentially interesting species in this aspect, according to a study carried out by St.Anna School of Pisa, were:

annual	perennial
fibrous sorghum (Sorghum bicoloT L., Moench),	thistle (Cynara cardunculus L.)
some of the Phalaris genus (Phalaris spp.)	miscanthus (Miscanthus sinensis Anderss.)
fireweed (Kochia scoparia Schrad.)	giant reed (Arundo donax L.)
kohlrabi (Heliantus Tuberosus L.)	millet (Panicum virgatum L.),

Table 3.1

The following crops have best characteristics: fibrous sorghum, giant reed, miscanthus and thistle (the zones typical of the last are the southernmost parts of Europe).

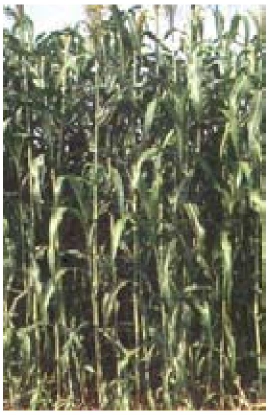
Another important source of biomass, as pointed out in the introduction, is the residues of grass crops, cultivated for commercial use. **The residual biomass for energy use is mainly in the form of:**

- straw, mostly from cereal crops (wheat, oats, barley, rice, etc)
- culms (for example corn, sunflower)

These wastes can have a use different from energy use (see table 3.2). The main purpose of straw production is usually for other agricultural uses, for example for bedding for animals or for drying facilities.

Corn should be given special attention (Zea mays L.), a plant with excellent yield. Hybrids were obtained through selection, which can yield dry matter of over 40 tons per hectare. Genotypes which are not sensitive to sunlight are late with florescence and direct most of the photosynthetic cells to the leaves and the stem, increasing the production of biomass. This, however, is a crop suitable for areas with good water resources.

Characteristics, yield, agronomic environment[2]



Fibrous sorghum (Sorgum bicolor)

- Annual grass species
- Average dry-matter annual yield: 28.2 tons per hectare
- Ash content: 5.6%
- Percentage of silicon in ash: 33.1%

Sorghum (Sorghum bicolor L. Moench.) is one of the interesting crops for production of biomass, due to its high degree of accumulating dry matter per day. It is a plant with C4 metabolism, with high photosynthetic efficiency, an extensively

CROP	RESIDUES	USE	PERCENTAGE OF USE
Soft and hard wheat	Straw	• Bedding for animals • Food for animals • Paper industry, etc • Burning on the field	40-50% 5-10% 5-10% 30-40%
Barley	Straw	• Bedding for animals • Burning on the field	50-60% 40-50%
Oats	Straw	• Food for animals • Burning on the field	40-60% 20-30%
Rice	Straw	• Bedding for animals • Burning on the field	20-30% 70-80%
Corn grain	Stems Cobs	• Food for animals (stems) •Burying (cobs)	10-20% 70-80%
Sunflower	Stems	• Buried	no data

Table 3.2 Debris from traditional crops and their use nowadays

2. Key to the tables the yield data given in the tables below, relates to the experiments, carried out on the territory of the valley near Pisa in Tuscany – s.s./ha = dry matter per hectare

branched root system and high water holding capacity. The central part of the stem is a pith which can be dry or sappy (as with sugar sorghum), with sugar content of 10 to 14%. This is an exceedingly suitable crop for areas with scarce water resources, because the silicon layer in the root endoderm impedes the crop to collapse during continuous drought periods, whereas the wax cuticle, coating its leaves and stem, limits the losses of water.

- Strong points: easily adaptable to various cultivation conditions. The use of this species as a source of biomass for energy purposes is facilitated by the simplicity of the different agricultural operations, analogous to those which are carried out for other grass crops, cultivated in the filed. Apart from that as an annual crop, it does not occupy the land for more than one season.
- Drawbacks: the biggest problems this crop presents relate to biomass quality, due to the high ash and silicon content in dry matter and high moisture content.

Miscanthus (Miscantus sinensis)
- Perennial root species
- Average dry-matter annual yield: 28.2 tons per hectare
- Ash content: 2.8%
- Percentage of silicon in ash: 56%

Miscantus (Miscanthus sinensis Anderss.) is a perennial species from the cereals family, originating from the Far East and imported in Europe some 65 years ago as an ornamental. Probably its life-span is 15 years or thereabouts, but data on this issue is scarce, especially concerning the effective duration of the period it is used both economically and energy-wise. In this respect the effect which the manner of seeding and fertilizing has on the crop durability and yield should be studied as well as that on the costs for its cultivation.

- Strong points: the average annual yield of dry matter is rather high (equal or greater than that of sorghum) and is less only than that of reed.
- Drawbacks: the plant has more demanding needs for water (especially when compared to reed); the mechanization of planting has not been improved yet, reinstatement of land after cultivation of the crop is difficult, due to the vigour of residues; the biomass is characterized by high silicon content.

Giant reed (Arundo donax)
- Perennial root species
- Average dry-matter annual yield: 37.4 tons per hectare
- Ash content: 5%
- Percentage of silicon in ash: 44%

The giant reed (Arundo donax L.) is a member of the cereals family, naturally spread throughout the entire Mediterranean basin. Within the framework of European projects the Institute of Agronomy in Catania has gathered some 40 populations in Southern Italy, distinguished for their considerable mutability in respect of the characteristics of agronomical importance for biomass yield. The yield potential of the plant is significant (>35 tons dry matter per hectare). There is, however, little information about the life-span of the species, as well as about the biology and physiology of reproduction, which is effected by way of an underground root system. Reproduction of the crop requires further study since this species does not produce seeds and therefore parts of the stem or rhizomes have to be used.

- Strong Points: undoubtedly, this is the most productive energy crop amongst those which have been experimented on in the Mediterranean climatic conditions. It is easily adaptable to different types of soil and climatic conditions, characterized by little rainfall. It is a perennial species, distinguished for its high yield over a long period of time. It is a typical component of Mediterranean rural scenery. It is efficient in protecting the ground against erosion.
- Drawbacks: the cost on using the roots is very high due

to both the price of the roots themselves (which will be reduced when the number of nurseries is increased) and the imperfect mechanization of this activity. This is a highly invasive species and a lot of work is needed, before other crops can be cultivated on the same terrain. The biomass is characterized by high silicon ash content.

Thistle (Cynara cardunculus)

- Perennial species
- Average dry-matter annual yield: 11.4 tons per hectare
- Ash content: 13,9%
- Percentage of silicon in ash: 15%

Species of the Cynara genus are perennial. They originate from the Mediterranean basin and therefore are drought-tolerant. They are considered to be of particular importance for the Mediterranean environment, due to their ability to propagate also through seeds, because of both their little impact on environment (require modest investment) and the fact that they are perennial and have a high energy value. The dry matter yield of the produce obtained in Tuscany is low; in Southern Italy, however, for Cynara cardunculus, sort altilis, the dry matter yield for some crops is 30 tons per hectare.

- Strong Points: This is a very tenacious plant, which adapts to conditions of scarce water and food resources. It is easily propagated through seeds and can yield other products apart from biomass (for example, seeds for oil extraction). The obtained product is easy to store.
- Drawbacks: registered cultivations in our land are not big (compared to other crops), and the quality of the biomass is not particularly valued, since it has high ash content.

Type of biofuel and energy qualities

It can be generally noted that the energy quality of biomass derived from grass crops or their residues is lower than that of biomass obtained from woody debris or from woody species of SRF. This is due to three main reasons:

- bigger ash residues
- lower melting temperture of the ash (at a risk of damaging the facilities, especially those which have to operate at high temperatures because of energy efficiency).
- presence of harmful substances, such as silicon, alkaline substances (potassium, sodium) and chlorine, due to the emissions or materials of the plant facilities. When reacting in the combustion process chlorine and alkaline substances form chlorides with a highly corrosive effect on the steel of the boiler and the pipelines.

The heat output of grass biomass is rather good, a bit lower than that of woody biomass of SRF, but still exceeding the minimum value required for combustion plant facilities.

All parameters – ash, melting temperature, undesired substances, lower heat output, present a problem if the feedstock fuel is crop residues, mostly straw.

However, there are two main reasons for the energy use of these residues:

- their greater ability compared to that of woody residues
- and especially – the possibility of easier and cheaper harvesting compared to woody residues or wood of SRF.

These findings are very important because the energy quality of grass biomass varies considerably for different crops. Based on the energy quality of the pellets, derived from the main biomass crops, the following conclusions can be drawn[3]:

Miscanthus (Miscanthus): although it has the lowest silicon ash content among the studied crops, it has very high silicon oxide content. The quantity of silicon (in absolute value per kg pellets) is much higher than that in the other energy crops. Depending on the combustion technology this can lead to damage in the boilers or too expensive maintenance.

Sorghum (Sorghum) contains all mentioned harmful substances in bigger quantities. In order to avoid this problem, an experiment was carried out with a combined pellet from sorghum and poplar in a 1:1 ratio, resulting in considerable reduction in all undesired parameters. The only adverse aspect was the reduction in the heat output, a result closer to that of sorghum than that of poplar.

The giant reed (Arundo donax) has a relatively low heat output, but the other parameters are close to the sorghum-poplar mix and therefore are good for grass biomass.

The thistle (Cynara cardunculus) has low heat output and high ash content, with strong presence of oxides and chlorides

3. The findings are the results of experiment and analyses, carried out in the Tuscany project 'Bioenergy Farm' of St.Anna School in Pisa using different material in the form of pellets derived from various grass and woody biomass and their ash

Table 3.3 Yield and energy characteristics of certain species for biomass (S.Piero a Grado – Pisa)

	Biomass *(с.в.) т/ха*	Caloricity *MJ/кг*	Energy content *MJ/ха*	Ash %
Annual species				
Kohlrabi (Helianthus Tuberosus)	5.6	15.1	386.6	6.9
Hemp (Hibiscus cannabis)	18.6	15.3	284.6	5.6
Fireweed (Kochia scoparia)	26.7	14.7	392.5	6.8
Sorghum (Sorghum bicolor)	28.2	16.4	462.5	5.6
Perennial species				
Giant reed (Arundo donax)	36.4	16.7	607.9	5.0
Thistle (Cynara cardunculus)	14.8	14.1	208.7	13.9
Miscanthus (Miscanthus sinensis)	37,4	16,9	632,1	2,8
Switchgrass (Panicum maximum)	17,0	15,1	256,7	no data
Guinea grass (Panicum virgatum)	11,0	15,2	167,2	no data
Comparison with coal		27,4		

Source: Angelini et al – PISA 1999

Table 3.4 Yield and energy characteristics for certain agricultural debris

TYPE	Yield *MJ/ха*	P.C.I. kcal/kg of dry weight
Straw	3	4100
Corn stems	8	4100
Sunflower stems	4	4300
Vine twigs	1,5	4100
Marc		4100
Hulls		3600

Source: ITABIA 2003

Table 3.5 Characteristics of burning of pellets, derived from the main crops

	Caloricity MJ/kg	Volatile fraction at 105° %	Absolute value of dry residue %	Silicon %	Potassium %	Calcium %	Chlorides %
Thistle	16.8	14.4	7.14	0.2	1.9	1.5	1.6
Giant reed	16.8	9.4	3.77	1.5	1.0	0.3	0.1
Miscanthus	17.7	21.9	1.40	55.6	0.1	0.2	0.1
Sorghum	17.1	10.6	7.46	3.2	1.4	0.7	0.5
Sorghum+Poplar	17.2	11.7	3.59	1.3	0.8	0.5	0.1
Vine twigs from pruning	18.0	9.8	2.86	0.3	0.7	0.8	no data

Source: Bonari et al. – Crops for energy use: The "Bioenergy Farm Project 2005"

Table 3.6 Melting temperature of ash from some vegetal biomass

	Initial T (°C	T (°C) of the fluid
Thistle	1221	1255
Miscanthus	1004	1074
Giant reed	1016	1034
Sorghum	1030	1059
Straw	800	850
Comparison with: coal	1180	1450

Source: Bonari 2005 + The Centre for Biomass Technology - Denmark

(the latter – to a higher percentage than what has been specified in Italian norms).

Heat production from woody and cellulose fuel, derived from woody species, can be considered as sufficiently clarified by science. The technology of burning grass biomass is still under development. Generally it is characterized by high ash content (most often melting at low temperature), which increases the risk of damage to the boilers, available on the market.

How to reduce the undesirable effects from the burning of biomass, i.e. – the large quantity of residual ash, the low melting point, and, most of all, the presence of harmful components?

The ten-year experience in Denmark on the use of straw for energy purposes (one of the fuels with worst characteristics among the studied biomass crops), is the basis for drawing some important conclusions regarding the improvement of its energy efficiency.

The residual dry matter of straw contains some 50% carbon, 42% oxygen, 6% hydrogen and small quantities of nitrogen, sulphur, silicon and other minerals, alkaline elements in particular (sodium and potassium) and chlorine. The presence of chlorine and alkaline minerals in the gas, which forms during the burning phase, is a problem, since these substances, when reacting, produce sodium and potassium chlorides, which are highly corrosive to the steel in the boiler and pipelines.

Ash is the cause for another problem from the moment when its melting point (800-850°) becomes relatively low compared to that of other fuels. This is an important problem, especially for those systems which have to operate at a high temperature in order to have high efficiency.

If a mix of straw and coal is used for fuel, due to the presence of alkaline substances, the ash, to differ from ashes of pure coal, cannot be used as a component of construction materials, but should be stockpiled at controlled locations.

The experiments, carried out in Denmark, however, show that the presence of chlorine and potassium in the straw which is left to decompose in the field is considerably reduced under the effect of rainfalls (from 0,49% down to 0,05% for chlorine and from 1,18% down to 0,22% for potassium).

In order to reduce further the corrosion effect of straw in systems, in 1996 ELSAM - Electricity Utility Group of Jutland-Funen, carried out trials for removing the undesired components by way of thermal processing of the straw at a temperature of some 160°C. It has been proved also that both chlorine and potassium can be washed out at lower temperatures of some 50-60°C.

Energy loss caused by the processes of washing out, drying and removing the undesired components, constitutes some 1'8% of the heat output of straw.

An efficient method of improving the quality of grass biomass is its use in the form of pellets.

In comparison to other forms of using biomass, such as wood chops, tree twigs, saw dust, etc., pellets have a number of advantages:

- apparent high density (650-780 kg/m3), which optimizes transport and storage;
- the quantitative and qualitative homogeneity of the material, which, collected in small volumes is easy to relocate and process;
- low moisture content (≤ 10%), which optimizes combustion and reduces the risks of fermentation in the storage period;
- high heat output
- possibility for mixing heterogenous feedstock.

The last characteristic is of significant importance for grass biomass, especially for straw or other debris, because, as the experiment with the sorghum/poplar pellets from Pisa has shown, the mixing of grass with woody biomass of high energy quality, allows for fuel with better characteristics to be produced by removing undesired components to a large extent.

Use of grass biomass for energy purposes

Energy conversion technologies: conversion of electricity and heat, cogeneration

The energy conversion of grass biomass plants is based on the current technologies in the field of energy conversion of woody biomass. Combustion is carried out in four phases. Free water evaporates in phase 1. Pyrolysis (conversion in gas) is carried out in phase 2, during which combustible gases form depending on the temperature. Certain amount of carbon oxide (CO), hydrogen (H2), methane (CH4) and other hydrocarbons always form in this phase. Combustion of gases takes place in phase 3. If oxygen is in sufficient quantities, combustion is complete and the only residual products are carbon dioxide (CO2) and water. If oxygen is insufficient, carbon oxide, soot, tar and not burnt hydrocarbons are produced. Finally, in phase4, carbon burns. In this phase CO_2 is produced as well, if combustion is complete, otherwise the dangerous CO is also produced. What is left is ash, consisting of non-combustible organic matter.

The main characteristics of grass biomass are given in table 3.7. Grass biomass is characterized by higher ash content compared to wood. Ash content is about 5%, depending on the studied plant species , the moisture content in fuel and other factors such as temperature and presence of oxygen during burning. Low-melting and corrosive oxides are rich in ash, which can damage modern boilers. This limits the possibilities for burning grass biomass, since it is required for special boilers to be used, in which combustion should be controlled in such a way as not to exceed 700oC (the softening temperature of ash, which at 600oC becomes glutinous). The more heterogeneous and crude is the output biomass, the higher the melting temperature. In optimum conditions the melting temperature of ash is even over 1000°C (table 3.6). In any case, this limit of temperature in fact reduces the energy effectiveness of heat generation, the more so of electricity generation. In fact, in order for good effectiveness to be achieved, high temperature of steam is required, but it leads to a risk of massive deposits forming on the pipes.

Today we consider ash as waste but it can have a very important application in agriculture. Apart from being used to determine the quality of the burnt material, ash residues can be used and sold as a fertilizer, which is an added value to the product. As noted, ash from grass biomass, combined with ash from woody fuel, softens at a considerably lower initial deformation temperature and this can result in deposits forming inside the boilers. For example in the case of fluidized bed boilers, deposits accumulate in the fluidized bed and the boiler stops operating. In the case of boilers with a moving grate deposits from fuel decrease the air flow through the grate and disrupt the burning process. If as a result from the reduced air inflow through the grate the temperature continues to rise, melting of the fuel and its ash can cause the system to stop. These drawbacks can be mitigated by using moving grates which are regularly flushed with water.

Another problem is the presence of chlorine and alkaline substances in the gases of the smoke flue. These substances react and transform into sodium and potassium chlorides, which are extremely corrosive to the steel of the boiler and pipes, especially in high temperatures. One way of reducing the content of chlorides and alkaline substances is letting straw decompose in the open, as described in the previous paragraph.

Apart from these drawbacks, due to the different types of fuel, there is not a big difference in the technologies of energy conversion of biomass derived from grass and woody fuels.

TYPES OF PLANT FACILITIES AND SCOPE OF USE

Before reviewing the different types of plant facilities for grass biomass we have to consider the issues related to transport and mechanized supply of input fuel. This is very important for small-scale systems, since chopping of straw for fuel requires a lot of energy and rather complicated chopping devices.

A possible solution is to use pellets, which, as evident from the experiments carried out in the Bioenergy Farm Project,

Table 3.7. Content of the main chemical elements in straw, compared to that in chopped wood (Sanders and others, 2000)

	Straw		Chopped wood	
	content-%, dry matter		content-%, dry matter	
	Typical	Norm	Typical	Norm
Ash	4.5	2-8	1.0	0.3-6
Si	0.8	0.1-2.0	0.2	<1.1
Ca	0.4	0.2-0.5	0.2	0.1-0.9
K	1.0	0.2-2.6	0.1	0.05-0.4
Cl	0.4	0.1-1.1	0.02	<0.1
S	0.15	0.1-0.2	0.05	<0.1
N	0.7	0.3-1.5	0.3	0.1-0.7

can be produced from different crops for energy use (save for thistle). The experiments with 8-10mm pellets of non-chopped straw carried out in Denmark showed that pellets can be used without any problem in large-scale plant facilities, but the formation of ash and cinders makes them less suitable for use in plant facilities of small capacity.

There are technologies allowing straw to be used without being chopped beforehand and also whole bales to be directly fed to the system. Figure 1 shows a model system with an automatic boiler, equipped with a straw chopper, as well as a boiler with a moving grate. The case in point is small-scale boilers, suitable for agricultural farms: the straw bale is chopped by a chopping device at a low rate. The fuel is fed to the boiler by a feed screw (fig. 3A) or falls freely (fig. 3B). The moving grate allows the ash to be regularly removed. Heat from combustible gases is supplied to the pipes where water circulates for heating the building.

There are such boilers of small capacity available on the market operating with dried corn grains. The capacity of existing boilers (20-93 kW) does not allow for corn to be considered as an energy crop. It should be underlined that the quantities of energy and water, consumed for corn grain production, exceed those for crops cultivated for energy use. However, prospects for energy use of condemned corn could be of interest, due to the exceedingly high content of mycotoxins. In any case the big advantage of corn grain is that it can be stored straight after harvesting from the field without any additional treatment. From the storage hopper it is automatically fed to the heat generator without any additional costs, for example for pelletisation. The melting point varies between 700 and 750°C and in order for the aforementioned problems with softening of the ash to be avoided; a fan should help maintain the temperature in the homogenization area in the range of 600 to 700°C.

Recently interesting experiments for the use of miscanthus in small heat generation plant facilities were conducted.

Save for an experiment in England with possible implementation (see Case Studies), the case in point are small plant facilities (in most cases at an experimental stage), using miscanthus pellets with control on the amount of output smoke and the amount of ash produced. The results seem very encouraging. It is calculated that 15 tons of pelletised miscanthus can be obtained annually from each hectare of land and the heat generated from them will allow for a saving of 6,000 litres of traditional petroleum to be made.

Among the plant facilities of medium capacity a special type of plant facility for grass biomass is the so called "cigar burner". It is a combination of a feed system using bales and a boiler with a sloping grate. The fuel does not require any preliminary treatment, which makes it possible for costs to be reduced. The bales are pushed forward onto a grid during the course of burning and reach the base of the sloping grate, when they are completely burnt. The system of vertical pipes allows the ash to fall into a filter with a sack. One drawback of this technology is the fact that the type and size of the bales have to be homogenous, because otherwise the release of CO is increased and the burning efficiency is reduced.

Examples of this type of systems are a co-generation plant in Haslev – Denmark, producing 5 MW of electricity and 13 MW of heat (the first plant for grass biomass in the world) and a small heat generation plant (3.2 MW) in Schkölen - Germany.

Power Plants of medium and mostly of large capacity can produce electricity as well. It is clear that combined power and heat plant facilities for cogeneration of electricity and heat are preferable.

- Plants for generation of electricity are 40-45% efficient, hence the heat lost to the surrounding environment, the atmosphere and the more so – water, comes up to 55-60%;
- In the production of heat only, an efficiency of 80% is achieved;
- In the case of cogeneration, however, electricity production reaches 20-30% efficiency, whilst heat production – 60%, meaning that the loss can be reduced to 10%.

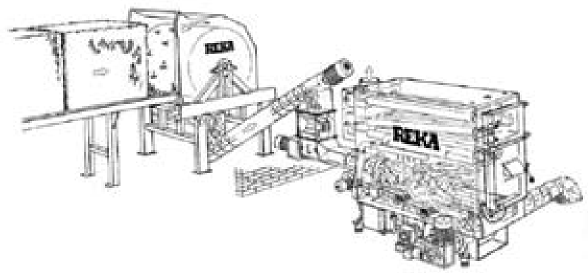
Furthermore, cogeneration plant facilities do not need water for cooling the system, and therefore can be suitably located in farmland areas for production of biomass.

Plants of greater capacity are not usually fuelled with grass biomass only. There are different examples of coal fuelled plant facilities, adjusted to operate on biomass and coal. These are power plants, which in the past were supplied with powdered fuel and now have been adjusted to burn a mixture of biomass and coal. They produce hundreds of megawatts of heat, but the share of biomass is limited (up to 20% of the supplied fuel).

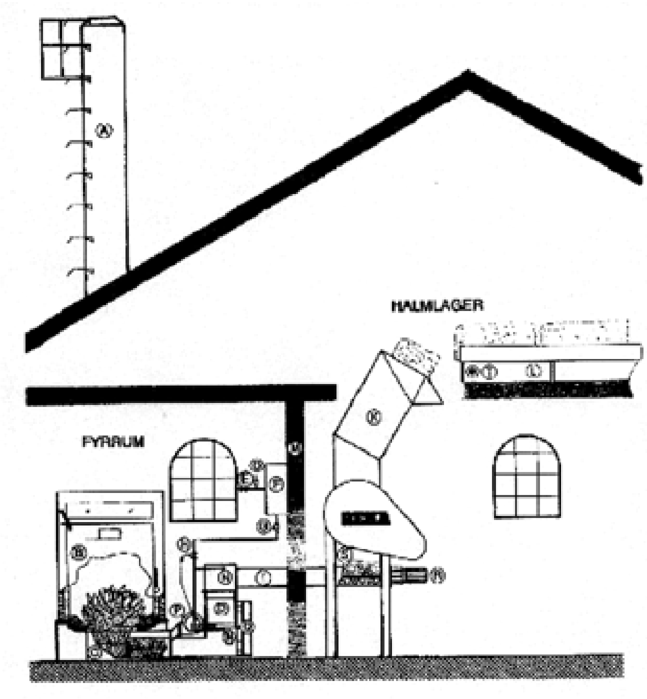
Fluidized bed boilers are generally used in plant facilities with production output exceeding 10MW. This technology allows for different types of fuels to be used, each having different moisture content. The combustion temperature is rather high, usually 800°C or therabouts. This, as it has been noted above, is the main obstacle to the use of grass biomass, especially of heterogeneous biomass, since ash starts to melt

Figure 3.1. Small capacity plant facilities for burning straw bales (www.reka.com)

A



B



A.	Chimney
B.	Boiler
C.	Air chamber with distiller
D.	Cell
E.	Non-return valve
F.	Pressure vessel
G.	Valve filter
H.	Sprinkler with valve fitted with thermo couple
K.	Dosing screw
L.	Stem cutter, type S 250
M.	Straw belt conveyor
N.	Wall BS 60
O.	Sprinkler with nozzle 180 deg.
P.	Pressure control
Q.	Combustion fan
R.	Gear motor (Feed screw and cell shutter)
S.	AC gear motor (Dosing screw)
T.	Dosing screw
U.	Gear motor for straw belt conveyor

at lower temperatures.

Economic Assessments

Payment for agricultural produce

During the Bioenergy farm project some preliminary economic assessments were made as well as an energy balance of crops cultivated for energy. These assessments have an interim and not final value, since in agrological aspect they relate to soils in the valley around Pisa. Moreover, they concern agronomical parameters only and not quality of the obtained biomass). The crops which have been analyzed in this experiment are:

- Sorghum (Sorghum bicolor L.Moench), with precise seeding, harvesting with a special mower, arraying in rows and baling the material in round bales;
- Thistle (Cynara cardunculus L.), a 10-year crop. Harvesting with a special mower, baling the material in round bales;
- Miscanthus (Mischanthus x giganteus Greef et deuter) planting with planting machine for tubers/roots at a distance of 2 m^{-2}, harvesting with a combined mower-chopper-loader (moisture content 53%), a 10-year cycle;
- Giant reed (Arundo donax) planting with planting machine for tubers/roots at a distance of 1.25 m^{-2},, harvesting with a combined mower-chopper-loader (oisture content 52%), a 10-year cycle;
- Poplar SRF (Populus spp.) planting of graft using forestry planting machine, density: 1 plant over a m^{-2}; harvesting with a portable machine type "feller-chunker" (moisture content 52%);

The following indices, obtained in the experiments in San Pietro a Grado, are given for production, and for reasons of discretion have been reduced by 20%. Apart from this correction (which is necessary for the assessment to be reliable), based on these experiments ITABIA state in their report from 2003 that the average annual yield of energy crops, cultivated in the open, is merely 10-15 tons per hectare. The conclusion is that in order for a yield of 20-25 t /ha to be achieved, agronomy practices should be improved and farm facilities should be re-organized. The results obtained in the Bioenergy Farm Project are given in table 3.10.

Generally it can be said that the average costs per crop (both costs for used specific production means and costs for mechanization of crops) are not very much different from those which are usually noted in agricultural farms in the valley round Pisa cultivating traditional grass crops in the open (grains for industrial purposes and/or animal husbandry). Total cost varies from 28.5 Euro /ton dry matter for miscanthus to nearly 50 for thistle. The costs are given for one year; for example in the case of reed (35 Euro /ton), which is a perennial plant, costs for crops and in particular bigger costs for materials for reproduction are deducted.

The estimated gross product for different crops has been calculated without leaving leeway for any form of financial assistance or reimbursement for agriculturalists. It is important that the previously existing concept of relating non food crops to abandoned farmland is overcome, and to take account of the net gain, which can be obtained from these crops, excluding financial aid. This is the time to note the importance of political and financial support for a sector which can bring about considerable benefits not only for agriculture, but most of all for environment and health. There are considerable differences in the gross product estimates for the studied crops, as follows: the giant reed has the best characteristics (significantly higher revenue, compared even to normal average revenue from grain and/or oil crops, achieved in Tuscany). Miscanthus also has very good characteristics as well as SRF poplar. Rather low are the characteristics of sorghum and totally unacceptable are those of thistle. In estimating the average annual revenue from a unit area there are top economic results also for reed, followed by miscanthus and SRF poplar. The sorghum and thistle results are totally unacceptable. In

Table 3.10 Economic appraisal of crops cultivated for energy (S. Pietro a Grado - Pisa)[4]

	Sorghum	Thistle	Miscanthus	Giant reed	SRF Poplar
Yield (in tons of dry matter per hectare annually)	22.5	10.1	22.6	30.9	17.2
Cost for technical means (Euro per hectare annually)	14.7	52	126	383	186
Cost for mechanic means (Euro per hectare annually)	698	438	519	690	530
Total costs (Euro per hectare annually)	845	490	645	1073	716
Estimated gross product (PLV) (Euro per hectare annually)	876	346	1291	1786	996
Gross proceeds (Euro per hectare annually)	31	-144	640	695	280
Cost for production of biomass (Euro per ton of dry matter)	37.6	48.3	28.8	34.6	41.6

terms of gross yield (PLV-CT), the energy crops which have shown the best economic results again are reed and miscanthus.

In order for economically more profitable schemes to be established for cultivation of energy crops, more profound research is required as well as with regard to the mechanization of main operations such as planting and harvesting. The biggest problems nowadays present planting perennial root crops such as reed and miscanthus.

In conclusion it can be said that cultivation of grass biomass for energy use in the studied production and ecological conditions entices some interest, especially in terms of current market prices for dry matter for purposes different from energy use.

The economic assessment does not take into account eventual stimuli with regard to agro-environmental measures in the Plan for development of rural regions (PSR) for the special crops in "sensitive" agricultural areas. Possible integration decisions of the EU for energy crops have not been taken into account either (presently they cannot be grown on uncultivated land). Neither are considered the measures for limiting greenhouse emissions in the atmosphere and storage of CO2, for which agriculturalists can receive grants proportional to greenhouse gas quotas. This can further motivate cultivation of crops for energy use and contribute to the considerable increase in production of grass biomass. In this sector the price of raw material for production of energy is not just the production price. It is affected by the fluctuation in prices for fossil fuels, which, as it is known, are on the increase. Propagation of cultivation techniques and their improvement will not be able to reduce production costs incurred on the agriculturalist.

Costs for plant facilities and investment appraisal

Denmark has a lot of knowledge in the field of burning of straw mainly from wheat and barley residues, and also from triticale (a hybrid cereal produced by crossing wheat and rye), oats, rapeseed and peas. This is so, because in the beginning of the 90s the Danish government decided to reduce CO_2 emissions by 20%. Straw is a biomass resource widely available in Denmark; therefore scientific research was directed to industrial use of new technologies, existing in the field of burning grass biomass. Of the 6 million tons of straw collected in 1996 15% were used for energy purposes. These data are based on calculations done for effectively working plant facilities in Denmark.

The selling price for straw is about 50-65 Euro /ton. In 1997-1998, for instance, producers form one Danish region demanded some 62 Euro per ton, whereas industrial buyers offered 50 Euro per ton, so they agreed on 51 per ton. In the same year in other regions straw was sold at 46 Euro per ton under the same conditions. When the issue of biomass energy was raised, it became crucially important for transportation costs to be included in the economic (and environmental) schedules, because otherwise the balance could not be considered at zero. A truck can travel 2-3 km with a litre of petroleum, emitting 2.7 kg of CO2. Therefore, it can be said that it produces approximately 1 kg of CO_2 per kilometer. A truck loaded with straw with 14.5 GJ/t heat output, weighs some 11-12 tons and therefore is some 170 GJ of energy. Starting with carbon, CO_2 emissions, reach up to 100 kg/GJ. If the straw loaded on the truck is burnt instead of coal, some 17 tons of CO_2 will be saved. This means that if the truck travelled 17,000 km for each truckload, the benefit of saving would be none. Should the truck travel 85+85 km, 1'1% of the benefit for environment as regards will be destroyed.

In other words, if the feedstock supply (as is often the case with big plant facilities) is hauled over a large distance, this could be to the detriment of benefit for the environment. If transportation costs are at the expense of the producer, this should not be to the detriment of his profit. It is very important to carefully choose the location of the plant facilities (especially if on a large scale), while at the same time to proceed to enter into agreements with local farms along the entire chain.

The contract for supply of straw should by all means contain the following terms and conditions:

- contract period and final delivery dates;
- quantity of contracted straw; measures in the event of possible increase or otherwise in the consumption of straw; measures in the event of outstanding delivery due to reduction of crops or estimated yields;
- delivery terms, including type, size and weight of bales, water content and possibly other physical and chemical data for the type of straw;
- the base price and price regulation approach according to the water content and delivery period;
- persons in charge of arbitration in the event of litigious issues.

According to Italian estimates (Itabia, 2003) the value of feedstock delivery affects the total value of the produced energy by some 45%.

As per Danish calculations one plant, which can process 125,000 – 130,000 tons of straw per year, has an initial cost of some €25 mln (Figure 3.2). This is an approximate value because the variables in these innovative plant facilities are numerous.

4. The money values to 31st December 2002 were used with regard to costs for production means, whilst regional rates were used for assessment of mechanic operations, (to 31st December 2002) as given by the Association of companies for agricultural plant in Pisa (reduced by 20% for the revenues of each company). Yields are given in average values, obtained from long-time experimenting, reduced in case by 20%, so that they account for differences in open-air cultivation..

Before the plant is built it is very important for an "energy zone" to be established, which is to take the produced energy and heat, by entering into a contract with local consumers and managers of the power distribution network.

1 million DKK = € 0.134 mln

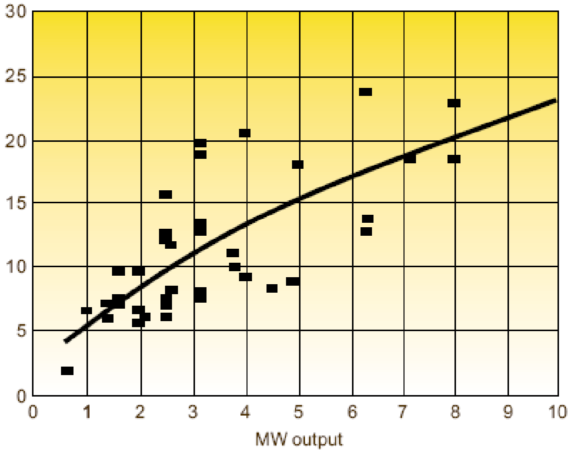


Figure 1.2 Construction costs in millions of DKK for installed MW, with up-dated prices for 1995, based on 40 plants, using solely straw. The price includes the site, the use of the ground, construction of the plant, installation of equipment and design work. Any change to the price depends on the size of the storage area, the quality of the plant, the variability of the market and whether the plant has at least one container for storing the straw.

The design phase of one plant for biomass requires on average 12 months and has a 5% share in the investment costs. The construction works take two to three years and the related costs constitute 90% of the investment value, if it is a newly built plant.

In the case of a plant working on traditional fuel being adjusted to work on biomass, these terms and costs could be reduced by 20-30%.

80% of investment costs are covered by the gang on generation and electrical and mechanic works. Civil associations and organizations for connecting to the network cover 9% and 5% of investment costs respectively. (EnEA, 2005).

Finally it should be noted that according to the Centre on international research on energy, environment and technological development (Ciemat) with the Spanish Ministry of Scientific Research, biomass has greater potential for creating new jobs. For example, the annual production of 1 TW/h of electricity from biomass would activate 1700 jobs, whilst at 1 TW/h from a coal source they would be 116, and from a nuclear source – 100.

As for the potential propagation of plants cultivated for biomass production in Italy, the factors which should be taken into account are numerous (structural, geographical, economic, social, etc.) and are not easy to satisfy. A preliminary estimate could show that 1 million hectares from the territory of Italy could be determined for seeding of annual or perennial biomass crops production for energy use. On the assumption that the average yield would be of the order of 100 tons of biomass per year, the total potential would be 10 million tons per year. (ITABIA 2003)

Case Studies

The straw-fuelled plant in Maribo – Denmark

The plant in Maribo- Sakskøbing in the southern part of Denmark produces combined heat and power through cogeneration. The electricity production of 9.3 MW is 29% efficient, which meets the needs of some 10,000 households. The heat production of 20.3 MW is 60% efficient (therefore combined efficiency is 89%), which meets the needs of the two neighbouring towns (the remaining 10% are supplied by a plant fueled by woody pellets).

The plant was commissioned in 2000 and cost € 32 mln. It is exclusively fuelled by straw, derived mainly from wheat, the consumption being some 40,000 tons per year. As an alternative, it can also be fuelled by wood, but in any case the moisture content of the fuel should be less than 25%.

Straw for the plant is supplied by nearby farms, which receive back ash and cinders they use for fertilizing. The straw feedstock hopper adjacent to the plant has a storage capacity of 900 tons, which means 4-day consumption at full capacity. The boiler is specially designed to operate with steam at 92bar and temperature of 542°C, as a result of which the abovementioned high efficiency is achieved.

The temperature of the smoke inside the chimney is 110°C, CO emissions are equal to 0.05% (with 10% oxygen) of the volume of the released dry gas. The gas released from the burning of the straw passes through a textile filter, which purifies the gas from the solid particles and is 99.99% efficient. Due to the efficient filter system the amount of dust leaving the system is 40 mg/Nm3, NOx is 400 mg/Nm3, and there are no SO2 emissions.

The plant facilities are decentralized and control on many maintenance operations is carried out by an operating plant facility, distanced at 120km. It comprises 4 major systems:

- taking the straw to the stoker;
- boiler;
- turbine and generator;
- energy zone for heat exchange.

A crane in the straw feedstock hopper places the straw bales onto an automated transporter, which hauls the bales to the boiler. There they are unbound and burnt in the combustion chamber. The combustion boiler has high efficiency and, as it was noted, removes sulphur completely from the released smoke. The burning straw is fed to a steam turbine, equipped with a generator of electricity. After having been through the turbine, the steam is fed to two heat-exchangers and it is then when it condenses into water. The water in the pipes is heated by the released energy and is fed to the energy zone heating it from 53 to 85°C. The hot water as such is pumped into the heat conveying system network and by way of a 7m long provides central heating for a quarter of the nearby town of Maribo (about 11,000 population), and by way of a 1.5m long pipeline – for Sakskøbing as well (about 9,000 population).

The plant facilities are equipped with an accumulator of heat consisting of a tank with a storage capacity of 6,000 m3, which is filled with hot water when consumption is low and provides it for distribution at peak consummation.

The Miscanthus Plant Project in Eccles Hall (England)

In Eccles Hall (in the vicinity of Stafford) the design phase of a plant is ongoing, based on a steam turbine, which is to produce electricity of 2 MW to meet the needs of some 2,000 average households. The main feedstock will be miscanthus and the alternative one – wood. Miscanthus will be grown by local agriculturalists over an area of more than 1,700 hectares in a radius of 40km from the plant. The annual consumption of biomass will be 22,000 tons. Ash production is estimated at 1,100 tons per year; this ash will be used as a fertilizer by the agriculturalists supplying biomass to the plant.

After commissioning the plant will work 24 hours a day, but it shall operate only 8,000 hours in the year.

The plant has been approved by the competent authorities on ecological issues in the country. The building contractor consists of two local companies and has been given one of the five grants within the "DTI Bioenergy Capital Grants" Project. The nearly 10 million Project will receive state financing and private investment, which will allow agriculturalists to use grants of € 625 per hectare for cultivation of miscanthus.

The use of most advanced technologies should reduce harmful emissions to a much lower level than the permissible limits by law. Noise and traffic factors have been examined in terms of incurring the least possible detriment to the local community. The community in turn would be able to find employment in the construction and maintenance of the plant.

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BIOGAS

What is biogas?

The biogas is a fuel gas, obtained during hydrolytic and digestion processes of high-molecular organic matter in the conditions of anaerobic oxygen-free medium. The decomposition of the organic components and the biogas production proceeds by the following scheme:

organic anaerobic
 > $CH_4 + CO_2 + H_2 + NH_3 + H_2S$
matter digestion

The biogas composition depends on a number of physical, chemical and microbial factors, and most often it is within the limits:

Methane (CH_4)	50 - 75%
Carbon dioxide (CO_2)	25 - 50%
Nitrogen (N_2)	0 - 7%
Oxygen (O_2)	0 - 2%
Hydrogen (H_2)	0 - 1%
Hydrogen sulfide (H_2S)	0 - 1%

The biogas contains nitrogen and sulfur if the initial feedstock possesses high protein content (for example, remains from slaughterhouses and processing dairies).

With this chemical composition, the biogas caloricity is 22- 26 MJ/m3 and depends mainly on the relative share of the methane (CH_4).

Where is the biogas generated

In natural conditions, the biogas is generated in places, rich in putrefying organic matter. The discovery of the biogas is connected with the name of Shirley who published in 1677 his work for the so-called "marsh gas". Later, in 1776, Volta called it "combustible air" and connected it with marshy areas, rich in rotting plants. Consequentially, Lieu Pasteur found out that the biogas is by-product from the activity of microorganisms.

Every day millions tons of waste organic matter are accumulated on our planet in the form of garbage, food wastes, faecal mass, bedding (a mixture of manure and straw), effluent waters, etc. During natural fermentation this refuse substrate is the source of millions cubic meters of methane, which is a "greenhouse" gas and represents 3 to 5% of the total quantity of all greenhouse emissions.

This represents relatively about 18% of the greenhouse effect increase. In this sense the uncontrolled construction of waste depots as well as the unorganized utilization of the waste biomass from agricultural operations (in particular, from stock-breeding) and the processing industry are a real factor for enhancement of the greenhouse effect and, at the same time, a potential source of renewable energy, boundless by its sizes. The technical-technological concepts for organized biogas production are imposed in three aspects:

1. Maximum reduction of the gas-methane in the atmosphere;
2. Decrease of the share of waste organic matter, directly environmentally deposited (in the soil and ground-based water sources).
3. Production of renewable energy (biogas) as an alternative of the conventional fossil energy sources.

The biogas – analogue and alternative of the fossil energy sources

According to its chemical composition, the biogas is to a certain extent an analogue of the natural gas. The difference is mainly in the relative share of the gas-methane. The content of methane CH_4 in the natural gas is about 95-97% volumetric. In the biogas the relative share of the gas-methane is 50–75%. This determines the relatively low caloricity of the biogas in comparison with the natural gas.

The average energy value of the biogas is 4,5 to 7,5 kWh/m3 (S. Stanev). For comparison, the energy value of the diesel fuel is approximately 10 kWh/l, of the firewood 4,5 kWh/kg and of the coal - 8,5 kWh/kg. In confirmation of the above-mentioned numbers we'll mention two other dependencies: 1000 l biogas are equivalent to 0,56 l fuel oil (according to Es. Kvalih). 1 kg waste biomass (dry matter) yields up to 1200 l biogas (depending on the substrate composition and the digestion conditions).

The analysis of the specified energy characteristics shows that the organized biogas production is an alternative of the conventional fossil fuels (fossil mineral resources – coal, petroleum, natural gas) as well as a real possibility to overcome the worldwide energy deficit.

In the process of biogas generation, the organic substrate undergoes considerable biochemical and microbial changes, as a result of which its chemical composition changes and it converts into the so-called bioslurry or compost. After an appropriate mechanical treatment (separation and pressing) the bioslurry contains dry matter of about 30-36%. Due to the mineralization processes (70% of the initial feedstock is mineralized), the compost doesn't possess any more the unpleasant odour, typical for the organic waste and its consistency is similar to that of the mineral fertilizers. The chemical composition of the bioslurry is characterized by high content of the main biogenous chemical elements C (carbon), K (potassium), P (phosphorus) and N (nitrogen) and by optimal carbon – nitrogen ratio. The mass chemical balance between the input and output material in the process of biogas generation is illustrated in Fig.1.

The content of the statutory regulated toxic chemical elements is far below the levels of maximum admissible doses. The colibacterial contamination is up to 10 per 1 g dry matter (at standard of 1000 for the organic fertilizers), and the salmonella and faecal streptococcal contamination is missing. After a technological retention of about 3-4 weeks, the bioslurry is used as a fertilizer, including for areas, prepared for production of ecologically pure products.

Feedstock base for biogas production

The initial feedstock for biogas production is called biomass.

The term biomass includes all organic substances of plant and animal origin. The chemical basis of the biomass consists of carbon compounds, similar to the content of the conventional natural fuels, but in contrast to them, the biomass is continuously renewing as a consequence of the photosynthesis, the activity of the living organisms and some anthropogenic factors.

Annually as a result of the photosynthesis 120 mlrd tons of dry matter are formed on the earth, which by its energy potential is equivalent to 40 mlrd tons of petroleum. The biomass is either specifically produced as a result of human production activities or refers to the use of wastes from operations in the agricultural, forestry, wood processing, wood working and food industries, of the communal farms and the scheduled environmental protection cares.

The biomass is divided into primary- microorganisms, plants, etc. and secondary – wastes as a result of human and animal vital activity as well as of initial biomass treatment. The biological wastes of livestock-breeding and plant-growing operations, the waste wood, the communal, industrial and other wastes possess a considerable energy potential. It can be described by the following example: for the simultaneous production of 1 kWh electrical and 1,3 kWh thermal energy by the co-generation method (simultaneous production of electric and thermal energy) about 5-7 kg of plant or wood waste biomass will be necessary.

Types of biomass

As mentioned above, the biomass s divided into primary – microorganisms, plants, etc., and secondary – wastes from the human and animal vital activity. In this sense we can conditionally classify the biomass in the following several groups:

1. Target-planted biomass

- energy tree species (tree species with intensive growth)
- energy cultures (maize, rape, etc.)
- cereals

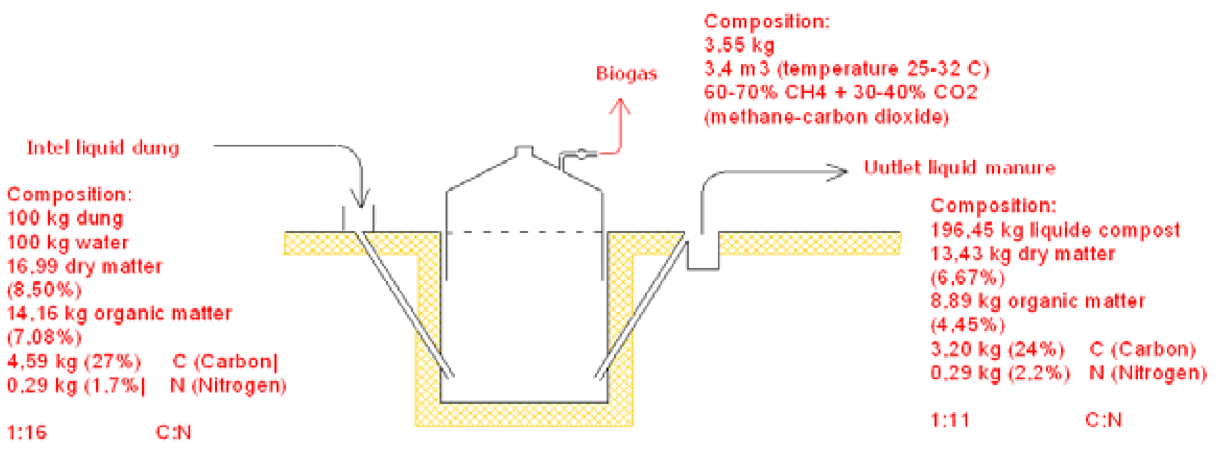


Fig 1. Mass chemical balance between the inlet-outlet substrate during methanogenisis

- oil-bearing cultures
- others

2. Plant wastes after agricultural activities, primary treatment and environmental maintenance

- straw;
- maize stalks
- sunflower stalks
- vine sticks
- fruit-tree branches
- tobacco stalks
- different types of straw
- hemp
- pasture and meadow wastes
- wastes as a result of bush liquidation and of terrestrial and grassed area maintenance

3. Livestock manure

- excrements and bedding of agricultural animals and birds
- forage wastes
- parallel production wastes
- others

4. Municipal organic wastes

- effluent water slurry
- organic wastes of solid municipal refuse
- others

5. Organic wastes of food and industrial production

- plant product treatment and storage wastes
- wastes from canning factories and distilleries
- wastes from wineries and breweries

6. Forest waste (dendromass)

- wood mass as a result of wood rarefaction (sanitary felling)
- branches, lopping, bark, leaves, etc.
- wood processing wastes (saw dust, shavings, manipulation pieces)
- others

The energy characteristics of some of the “basic” bioresources for biogas production are presented in Table 1 (according to St. Stanev)

Characteristics of some basic types of feedstock for biogas production (for 1 t feedstock) (according to St. Stanev)

Feedstock	DM Dry matter %	°DM Organic dry matter %	Gas output 1/kg°DM	Biogas m3
Liquid cattle dung	10	81	400	32,4
Fresh cattle dung with straw bedding	22	83	420	76,7
Pig dung	7	81	450	25,5
Fresh sheep dung	27	80	750	162,0
Fresh bird dung	15	77	654	53,7
Horse dung	28	25	580	40,6
Brew mash	25	66	700	115,5
Apple pulp	3	95	500	14,2
Apple marc	25	86	700	150,5
*** Green grass waste	15	76	450	51,3
Cut green mass	42	90	780	294,8
Potato stalks	25	79	840	165,9
Rape and fruit marc	45	93	670	280,4
Cornstalks	86	72	900	557,3
Barley straw	85	85	500	361,2

Table 1.

The next table (2) presents the average gas output of the most common organic wastes from the processing industry and the domestic waste

Type of waste	Average gas output m3/kg°DM
- slaughterhouse wastes	0,34 – 0,71
- fish processing wastes	~ 0,5
- food and forage industry wastes	0,32 – 0,8
- fresh effluent water slurry	0,39 – 0,41
- herb extraction wastes	0,2 – 0,75
- paper and board industry wastes	0,2 – 0,3
- biowaste of domestic farms	0,4 - 0,58
- biological oils and lubricants	> 0,5
- biodegradable packing materials	~ 0,64
- skim waste, oils from industrial canteens and gourmet companies	0,7 – 1,3

Table 2.

Explanation to the abbreviations in Table 1 and Table 2.

DM Dry matter in %

°DM organic dry matter in % out of the DM quantity

*** average for all types of plant wastes, connected with the floriculture, horticulture, greenhouse production, etc.

Some issues related to the biomass

The larger part of the above-mentioned waste products is with a conditional significance as sources of biogas. Those of them (corn and sunflower stalks, vine sticks, leaves, bushes, etc.), which are with high lignification level, posses very low methane-gas yield, they extend the digestion period and decrease the caloricity of the obtained biogas. In this aspect their utilization is possible only after a precise technological and economic analysis.

There are also certain problems with the use of cereals and straw as sources of biogas production. Since the dry matter content of that feedstock is above 80%, after the necessary technological fragmentation or cutting it should be diluted with water or other liquid wastes. Technologically this aggravates the preparation of the output biomass and requires additional power consumption.

The problems with the waste feedstock of the food industry (slaughterhouse wastes, dairies wastes) and some domestic refuse products exist in two aspects:

First, in most of the enlisted waste resources, the protein content is very high. During digestion, formation of H2S (hydrogen sulfide) will be expected. Under these circumstances, the obtained biogas should be additionally desulfurized until reaching level and concentration, lower than the values, set out in the operative statutory regulations. The desulfurization plants require additional initial investments and continuous "current" monitoring of the composition and quality of the obtained biogas.

Second, when slaughterhouse and domestic waste products are used, the cutting and fragmentation of the feedstock is necessary to obtain particle sizes, not larger than 5-6 mm. The fragmented mass is subject to pasteurization at temperature of about 700C for 1 – 1,5 h. The feedstock retention in the pasteurizer can be reduced but this will require a more powerful thermal source (the pasteurization runs at temperature above 800C). In this aspect, when biogas projects are developed on the basis of these feedstock types, the additional investments for the pasteurizing vessel and the transport line should be taken into account as well as for "the return" of part of the produced biogas energy in the form of heat for the thermal operation of the pasteurizing vessel.

Certain problems exist with the utilization of effluent water slurry. This type of feedstock contains very low dry matter content – about 2-3%. During "independent" digestion of such biomass, the gas output is very small, thus making more expensive and economically inexpedient its use. In order to overcome this restriction, it is necessary the effluent water slurry to be combined with another type of biomass so as the organic matter concentration in the "mixed" substrate to reach about 10-12%.

Which type of biomass is with the highest energy potential?

Out of the group of target-planted biomass, the maize possesses the highest biogas indices. In order to realize its maximum potential, the maize should be picked up in the phase of growth when its dry matter content is about 30%. The technological retention of the green mass between its picking up and feeding in the digester should be reduced to the minimum.

Within the group of the secondary biomass, the fresh dung mass from pig and cattle breeding operations possesses the highest potential. In order to extract the maximum possible biogas product, the dung mass should be fed to the digesters as soon as possible. Each continuous retention of the dung mass presupposes a natural aerobic digestion as a result of which the gas output consequentially decreases.

Biochemical and microbial processes in the biomass

The process of biogas generation presupposes a number of biochemical processes in the substrate on the basis of a very complex symbiosis between separate microorganisms.

The methane-generating bacteria are very sensible to the oxygen. Their life activity begins when the aerobic bacteria have consumed the oxygen in the food medium and its content has dropped below 2%.

In summary, the methane fermentation runs through three stages.

During the first stage, as a result of biochemical hydrolysis, the high-molecular compounds (carbons, fats, proteins) dissociate into organic compounds with lower molecular mass.

During the second stage, with the participation of acid-forming bacteria and further biohydrolysis, organic acids are formed as well as their salts, spirit, CO_2 (carbon dioxide) and H_2 (free hydrogen). Most of the obtained organic acids are a nutrient medium for the reproduction of the methanogenic microflora.

During the third stage, the bacteria finally transform the organic substances into methane (CH_4) and carbon dioxide (CO_2). At that stage a considerable quantity of free hydrogen (H_2) is released. Under the influence of a group of facultative anaerobic microorganisms, the released hydrogen and carbon dioxide appear an additional source for methane generation.

In general, the reactions during the three stages occur simultaneously but the methane-generating bacteria possess considerably higher requirements to the environmental conditions as compared to the acid-forming ones. Thus, for example, the methanogenic bacteria need strictly anaerobic conditions and a considerably longer reproduction time.

The process of biogas generation runs through three stages, which can be described basically with the following scheme:

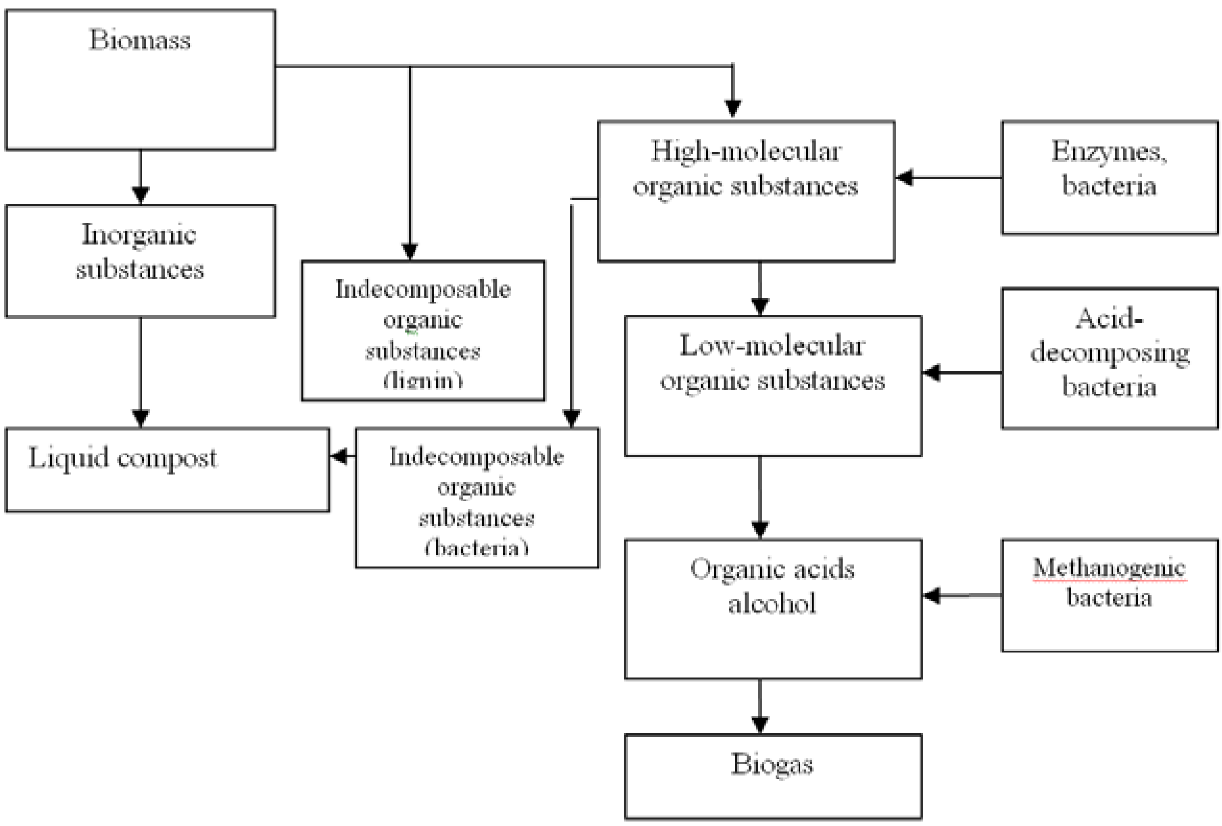


Fig.2. Principle scheme of the biogas generation stages

The speed and scope of the anaerobic methane digestion depend on the metabolite activity of the methane-generating bacteria. In order to increase the relative share of the methane in the released biogas it is necessary to observe the impact of a number of factors on the biochemical processes in the substrate.

Factors of methanogenesis

Presence of air (and O2)

Currently about 10 different methane cocci and methane bacteria are known, which are strictly anaerobic. If the O2 content in the substrate is above 2% it should be first spent by the aerobic bacteria, characteristic for the given type of biomass. This is done in the first stage of the biogas process. The inconsiderable quantities of oxygen, obtained during the technological desulfurization blow-through, are not harmful.

Substrate humidity

The methane bacteria can exist and reproduce only in case that the substrate humidity is minimum 50%. The extreme humidity (94-95%) presupposes low efficiency of methane generation.

The practical results to date show that with 2% dry matter content, "the methanogenic processing" for biogas production is not profitable. Dry matter content in the range 8-12% is accepted as optimal and ensuring high quality (methanization) of the produced biogas. With 12-16% dry matter content, the substrate can realize maximum gas output, yet it requires precise control and regulation of the number of bacterial strains. For substrates with dry matter content above 20%, the liquid method of biogas production cannot be applied and the moisture and dry methods require equipment with considerably larger capacity.

Light protection

The light is not a bactericidal factor for the methane bacteria and it reduces considerably their metabolism. The light protection is technologically easily feasible and doesn't require additional control.

Temperature conditions

The microbiological activity of the methane bacteria ceases almost completely at temperature of 150C. Regardless of that, the interval 0-700C is accepted as "working" temperature zone. The research biogas installation Sirvinton in Lithuania has found out a minimum quantity of gas even at temperature of 00C in liquid fresh dung. At temperatures above 700C (with the exception of several strains of methane bacteria, enduring temperatures above 900C) the methane bacteria die.

Three typical temperature areas have been practically established in which the respective bacterial strains display highest metabolism:

- psychophile area – strains, reproducing at temperature below 200C, respectively;
- mesophile area – strains, reproducing at temperature between 25 and 300C, respectively;
- thermophile area - strains, reproducing at temperature above 400C, respectively.

The main rule accepted says that the higher the temperature the more intensive the decomposition process, and the larger the gas release, the shorter the digestion duration, but the relative methane content in the biogas decreases (at the account of the carbon dioxide). Besides, at higher temperature regimen, the bacteria are very sensitive to the temperature decrease fluctuations although being short-term. For example, in the mesophile area the daily variations of 2-30C almost don't affect the bacterial metabolism while in the thermophile area daily variations above 10C should not be admitted. Currently, most biogas units operate in temperature modes between 30 and 350C. A tendency is observed in the collecting units the temperature to decrease within the range 20-250C with the purpose of saving technologic thermal energy. On the contrary, the fermentation co-generators display a tendency of increasing temperature regimen above 400C with a view of the larger power-thermal connections of these units.

The influence of these temperature areas on the biogas output is presented in Figure 3.

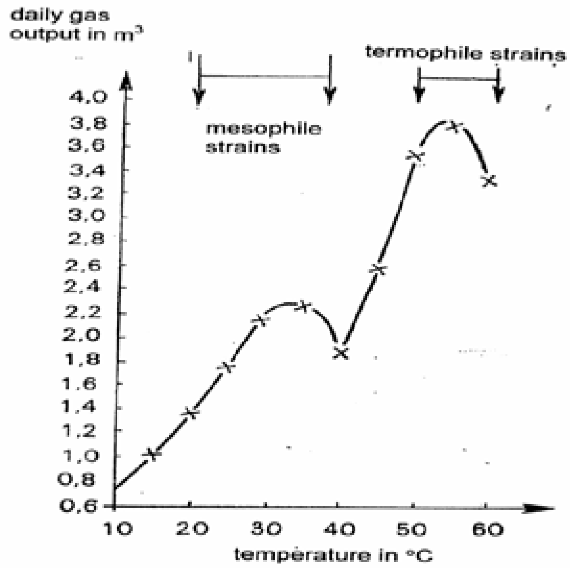


Fig. 3 Temperature effect on the biogas generation

The scheme shows that a relatively weak temperature change is necessary for optimal living activity of the separate bacterial strains.

The fermentation temperature regimen affects directly its duration, hence – some technological and project parameters. In operation methods under lower temperature, the tanks should be with larger capacity since the substrate retention time in the digester is increased. When the operation mode requires higher temperatures, the capacity of the tanks should be reduced.

The curve of the methane generation intensity when the mesophile and thermophile methods are applied is presented by the graphics in Figure 4.

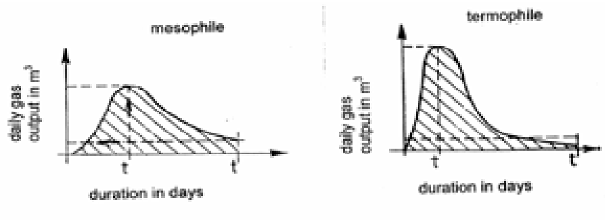


Fig. 4 Gas generation dynamics during mesophile and termophile regimen

The mesophile fermentation method is characterized by a certain smoothness within the time while the thermophile method presupposes quick positive acceleration of the bacterial metabolism, followed by similar in intensity, yet negative progress.

The range of the optimal temperature limits as well as the corresponding duration of the substrate decomposition are shown in Figure 5.

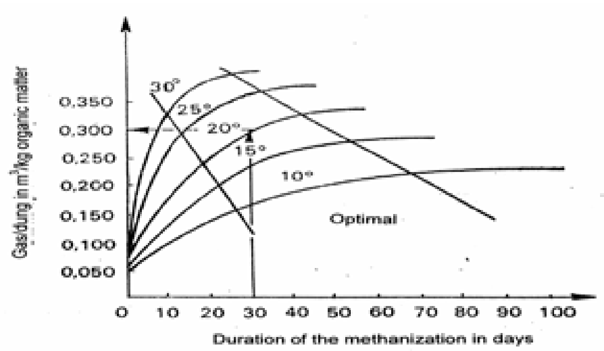


Fig. 5 Temperature top limits duringbiogas production

During optimization, the biogas output, the investments and the overall construction cost are specified. The calculations are made for the economic and climatic conditions of Western and Central Europe.

pH of the medium and level of digester loading

The influence of the pH of the medium on the biogas and methane-gas output is illustrated by the graphics in Figure 6.

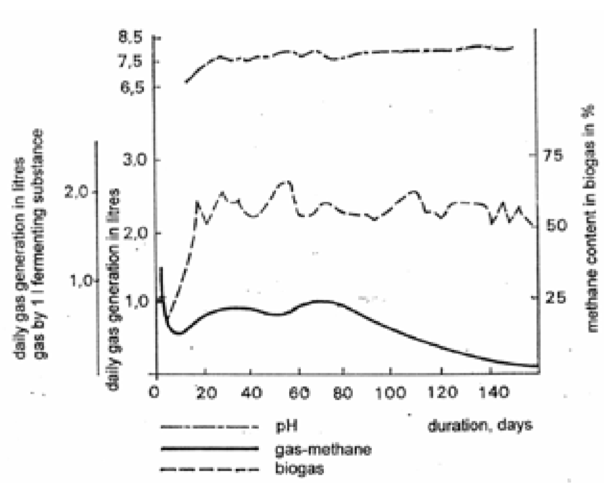


Fig 6. Biogas generation process (gas composition, pH changes)

The pH value should correspond to a slightly alkaline medium – about 7,5. For liquid manure and common cattle dung this area is found out during the second digestion phase.

For acid substrates such as marc, whey and silage, it might be necessary to add lime or another alkalifying component.

The chemical reaction of the medium (pH) is indirectly connected with the loading regimen of the digesters as well as with the ratio between the organic mass quantity and the methanogenic microflora concentration. Both the excessive and the insufficient quantity of organic matter change the curve of the expected product. This is a result of the microbiological dependence determining the syntrophile course of the organic matter decomposition.

If a given bacterial strain prevails, the equilibrium in the production process will be disturbed.

The problem most often faced in this aspect is the insufficient quantity of organic matter, fed into the digestion chambers. In this case the bacteria, which dissociate organic acids prevail and the substrate's pH strongly decreases. This dependence should be carefully "weighted" at the design stage in order to avoid digesters with unreasonably large volume.

The level of digester loading with substrate affects also the gas production. The dependence is described by the graphics in Figure 7.

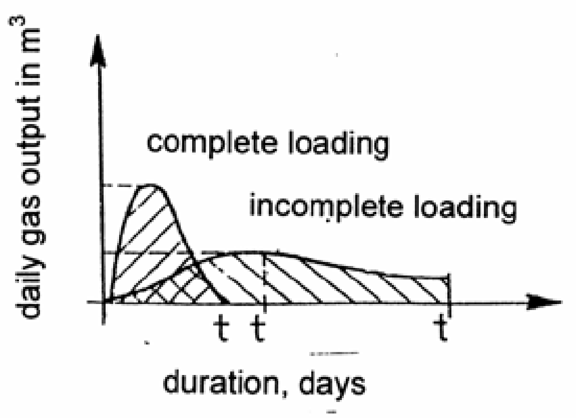


Fig. 7 Effect of the digester charge level on gas production

The complete loading of the digester determines the intensive biogas generation. The insufficient substrate in the chamber reduces the specific average daily gas output and the digestion time is extended.

Provision of food substances

The methane bacteria cannot directly decompose fats, proteins, carbohydrates and cellulose in pure form. Basically, they need soluble nitric compounds, ensuring material for their cellular substance. In order to achieve the maximum possible gas output, the carbon – nitrogen ratio is very important. In practical aspect the C : N ratio is recommended to be within the range 1 : 1,5.

Mechanic treatment and substrate surface

The organic substances, insoluble in water should be either finely distributed (for example, with addition of fats to be well emulsified) or so structured (for example, cellulose) as to obtain considerable contact-reaction medium. Materials such as straw, long grass or other biological wastes should be fragmented (recommended sizes 5-10 mm) and, if possible, their fibrous structure should be destroyed. Failure to observe the specified requirements results in extension of the digestion time, silting of the free water surface, mechanical problems with pumping out and stirring the substrate.

Equal substrate feeding

In order to avoid excessive loading of the digester feeding zone, the equal feeding in short intervals is advisory, let's say one or two times on a daily basis. This is valid both for the main substance and (even more important) for the high-concentrated additives, for example, fats. The rhythmic digester feeding averts the unforeseen temperature decrease of the substrate in the feeding zone.

Substrate degassing

High digestion effect can be achieved through the methane bacteria only if the biogas is continuously discharged from the substrate. If the biogas is not eliminated from the digestion volume, the result might be hazardous gas pressure and under certain conditions, different damages and failures may occur.

In slightly liquid substrates many gas bubbles are produced, which can evoke abundant substrate foaming. In agricultural waste with high dry matter content (above 5%), additional degassing should be carried out at the account of multiple stirring of the substrate.

First biogas installations, development and propagation

The first biogas production installation in the world was commissioned in 1856 in Mantunga, near Bombay. In 1939 the Scientific Research Centre in Agriculture in India started research with governmental funding. Today, most biogas facilities there are built and operated by the company Kadi Village Industries Commission (KVIC) with governmental subsidies.

In France and French Algeria about 1930 the construction of biogas installations was promoted on the basis of the patent of the Frenchmen Dusselie and Izman.

It was in that period that the installation for continuous biogas production by effluent waters was developed by the Frenchman Imhof. Consequentially, this project was improved as an industrial system for biogas production – type Schmidt-Egersglus. It is famous in the literature and practice under the name Bihugas.

Basically, the information for the biogas installations, built in Europe before the World War Second is contradictory and not very precise. Despite this, unambiguous data exist which show that such facilities have been operating first in France, Germany, Switzerland and Austria. The efforts were directed towards biogas production by all effluent-water treatment plants. According to the same data, the number of biogas installations, functioning with humidified domestic and agricultural wastes in Europe and North America has been approximately 2000.

In the years after the World War Second the energy market structure and the low petrol prices diminish the interest for biogas in Europe. The method was further developed mainly in India, China, Korea and some countries of the Third world.

The issue for waste treatment for biogas and energy production arises again after the drastic jump of the fuel prices in the period 1976-1977. Thus, only in the USA 18 methods for biogas production were patented in 1980. In the period 1981-1982 the Royal Academy in England, the Agricultural Chamber in Austria and the Institute for Quality Control in the Federal Republic of Germany were involved in collection, processing and evaluation of the investments for biogas facilities. Now in Denmark (Farm Gadegaard) the visit of biogas installation is organized in the form of a tourists' attraction at the price of 10 Danish krones per visitor.

In Switzerland the Scientific-Research Institute in Agricultural Economics and Mechanization (Tenikon) supervises the practical trials of the biogas installations at the International Fund for Energy Research (NEEF), built for the secondary and higher education.

Since 1981 the European Regional Bureau of FAO has assigned to France the coordination and evaluation of the European research on the biogas issues.

To date, by approximate data, there are 1000 biogas installations in Germany, 200 in Austria, 100 in Switzerland, 30 000 in Korea, 500 000 in India and about 7 million in China.

Currently the biogas technologies are developed most vigorously in Germany. In the separate provinces the biogas installations are being registered in special records. A Professional Biogas trade union has been established. According to its optimistic prognoses, in the next ten years there are resources and capacities to build about 22000 installations, involving farmers, consultants, engineering bureaus, manufacturers and permit offices.

Principle scheme of biogas installation for liquid substrates

Fig. 8 presents a principle scheme of biogas installation with vertical digester and realized version of complex biogas utilization.

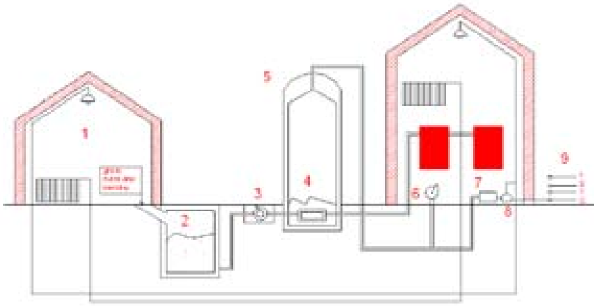


Fig.8. Scheme of biogas facility with digester:

1-cattle-ched with animals; 2-intel shaft; 3-pump; 4-digester; 5-biogas;6-water heating; 7-internal combustion moter; 8-electric generator; 9-transfer to the consumer

The organic wastes are fed into the inlet shaft 1. The preliminary mass homogenization is performed through the pump 2. The same pump delivers the substrate to digester 3. It is designed and manufactured in such a way as to ensure the necessary conditions for the process of methane digestion of the supplied biomass. The obtained biogas is directed to a burner, fixed on boiler 5 for water heating. Another part of the biogas is fed to a gas motor, which drives the electric current generator 7. The produced electric energy is supplied to the mains 8.

The next Fig. 9 presents a principle block-scheme of biogas installation with horizontal digester.

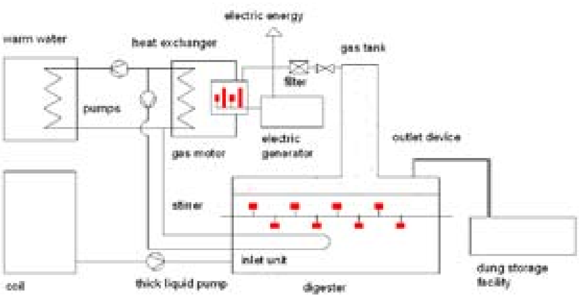


Fig. 9. Scheme of biogas facility with horizontal digester

The preliminary feedstock treatment (cutting, homogenization, dissolution, heating) is made in the fresh waste tank. A pump for thick liquids delivers the feedstock to the digester. Its mechanic stirrer maintains the fermenting mass homogeneous. The digester is completed with a coil (heat exchanger) for maintenance of the temperature mode according to the designed regimen (mesophile or thermophile). Through the discharge unit the processed material (bioslurry) goes to a dung depot. The gas collected in the gas reservoir (gas holder) passes through the cleaner for filtration and eventual desulfurization, then is fed to the gas motor. It drives the electric generator, which produces electric current.

The hot water from the cooling system of the motor (with temperature about 900) passes through a heat exchanger, type water-water or, ethylene-glycol-water. The thermal energy of the "cooled water" through the heat exchanger warms up water, which is used to maintain the temperature regimen of the digester chamber and the remaining water is used as a heating source for homes, production premises or for production purposes.

The schemes in Fig. 8 and Fig.9 are principal and they don't present the technical-technological details and operation parameters of the biogas facilities.

Technical equipment completion of the biogas installation

Provision of the technological processes

Substrate handling and storage

The concepts for biogas production in the modern installations are rarely developed on the basis of "own production waste" only. With a view to achieving higher efficiency, additional substances – coferments, are also introduced. In most cases these are substrates, delivered by "external" sources with a certain periodicity. This requires the construction of transport silos for acceptance and temporary deposition of the biomass. (Fig.10).

Fig 10. Transport silo to a biogas installation

In the farm biogas installations the substrate is stored mainly in the open. In accordance with the regulations for environmental protection and maximum reduction of odorous emissions, different construction facilities are organized to the acceptance depots, such as

shafts, bunkers, etc. They are designed so as to provide certain "purification" of the substrate in order to eliminate occasional solids – metal subjects, stones, etc. The large-scale introduction of liquid coenzyme components requires the construction of closed storing platforms and heating reservoirs (Fig. 11).

Fig. 11 Store depot for coferment

Fragmentation and dissolution of the biomass

To ensure the appropriate vital and fermentative medium for the methane bacteria, the biomass fed in the digester should be destructed – disintegration process. According to the type of the initial substrate and some other investment criteria, 4 types of disintegration are practically applied.

1. Mechanic crashing (grinding and dissolution)

This is the method, most often applied for plant feedstock and bulk coferments. By using a macerator (crusher) (Fig.12)

Fig. 12. Macerator (mechanic crusher)

or a hammer grinder, the material is fragmented, thus increasing its contact surface for the subsequent process stages.

2. Thermal dissolution

This disintegration method is recommended for initial substrates, requiring pasteurization (slaughter-house refuse, food operations wastes, etc.). Lately, experiments are carried out with a version of the thermal dissolution – a thermal pressure hydrolysis. In this version the substrate is subject to pressure of 40 barr and temperature of 160°Cto 180°C with duration of 60 days. Under these impacts 70% of the organic substances are dissolved – "nutritive bullion" for the methane bacteria. The application of this method requires the construction of an autoclave – uperizer (Fig.13) for control of installations, operating under pressure above 20 barr and temperature above 110°C. The thermal processing diminishes considerably the retention time (HRT) in the digester, thus increasing vastly the installation capacity.

Fig.13. Autoclave for thermal processing under high pressure

3. Chemical dissolution

This method is not very popular in the farm biogas installations. It is actual when, with a view to achieving the optimal carbon : nitrogen ratio (C/N), straw is added as a coferment. In this case it is recommended to use solution of sodium base (NaON) for the purpose of hydrolyzing the cellulose, insoluble in other cases.

4. Physical dissolution

This is an innovation method in the biogas practice, based on the use of ultrasound. In the frequency range above 20kHz when ultrasound processing is applied of liquid media, the result is cavity effect – a short-term appearance and quick decomposition of water vapour bubbles. During this effect the values of the surface pressure and temperature on the separate substrate particles grow high, which, consequentially, destruct and dissolve the biomass. The methods of electronic irradiation with different wavelengths are in a process of approbation.

Method of substrate feeding

The use of liquid dung and plant coferments for biogas production requires the construction of building facilities and the use of technical equipment for adequate substrate feeding into the digester. Depending on the accepted construction decision and the involved equipment, the digester feeding is provided in two schemes.

1. Hydraulic feeding system

The construction decision is based on the preparation of a ditch with capacity for substrate storage of maximum 1 to 3 days. The dung enters the ditch gravitationally through an inclined platform or is pumped out from the shed by thick-liquid pumps. The ditch is most often made by concrete (Fig.14).

In order to decrease the odor emissions it is recommended to envisage a cover structure for the ditch. The ditch functions as a depot and serves to solve problems, connected with substrate homogenization and fractioning, it provides suitable conditions for the pump equipment, it creates conditions for sedimentation and separation of occasional heavy admixtures.

Fig. 14. Reception shafts

The pump equipment, used in the hydraulic feeding system, is most often poly-functional. The pumps are structurally fabricated so as to ensure both transportation and fragmentation and mixing of the substrate (Fig.15).

Fig.15. Rotary pump in combination with "Biocutter"

2. Mechanic feeding systems

The basic element of the mechanic feeding system is a type of conveyor, driven by an electric motor. Depending on the design of the operating unit, the principle of substrate agitation, the volume and dosing capacity, the conveyors are several types.

- Screw conveyor with a funnel (Fig.16), feeding a screw conveyor in vertical and horizontal position

This equipment is suitable for small biogas installations. The funnel serves to accept the substrate from a front loader. It is not envisaged as a biomass tank.

Fig.16. Screw conveyor with a funnel

The screw conveyor is most often with diameter of 500 mm, it is driven by a planetary reducer and is aggregated by an electric motor of about 4kW electric power.

- Forage agitator

The forage agitator is a variety of the screw conveyor whose technological concept is mixing of the substrate, fed into the digester (Fig.17).

Fig.17. Forage agitators with screw conveyor and screw feeding conveyor

This version of conveyors is very suitable for intensive charge of solid substrates. The structure and control of the conveyor allow both mixing and dosing of the charged mass. The dosing process is controlled by time and weight.

In comparison with the screw conveyor with a funnel, the forage agitator is considerably more energy consumptive. The energy expense (especially during commissioning) can be considerably decreased by using a frequency transformer.

- Mechanic feeding by pressing conveyors with Wolf Machine system for solid substance (Fig.18).

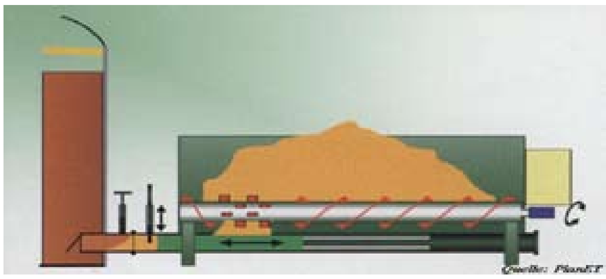


Fig.18. Wolf Machine system for solid substance

With this system the feedstock is transported from a store tank with capacity 13-18 m3 by the help of two hydraulic screw conveyors, moving against a horizontally positioned cylinder, from where by means of a piston the mass is pressed and pushed into the digester. In comparison with the forage agitators, this type of conveyors is characterized by low electric energy consumption (about 3 kW).

Digesters for biogas installations

The digester is the basic element of a biogas installation. It is there that the biochemical and microbial processes run, thus producing biogas. In order to provide the necessary conditions for substrate digestion, the digester should comply with the following requirements:

- Air-tightness in regards to gas and liquid. The air-tightness should be time-persistent.
- Light-protective;

- Thermally stable;
- Corrosion resistant;
- It shall afford pumping, stirring and circulation of the substrate.

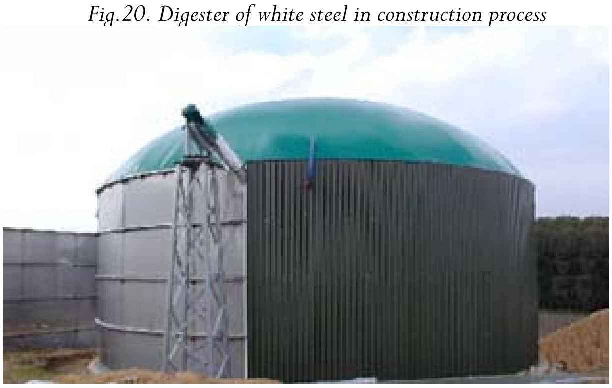
Depending on the construction material and the method of compliance with the above requirements, the digesters can be several types:

Fig.19. Concrete digester with insulation

1. Concrete digester with insulation (Fig.19)

This is one of the most frequent construction versions of digesters. It meets all mentioned requirements. With the time passing by, the micro-cracks on the internal surface erode and the concrete resistance to the chemically active medium vastly decreases.

Fig.20. Digester of white steel in construction process



2. Digester of white steel (Fig.20).

For this purpose white steel is applied (V2A, and, in the gas zone V4A) or, enameled steel sheets. When such materials are used, special attention should be paid to the external front of the digester. It should be "lined" with thermal insulation, resistant to atmospheric effects.

Tempering system of the digester

The tempering system has the purpose to maintain the necessary temperature mode in the digester, regardless of the external atmospheric conditions and the technological processing of the substrate. Major requirement to the tempering systems is the non-admission of large temperature fluctuations rather than the precision class controlling the maintained temperature. In addition, the tempering system should guarantee an equal temperature gradient in all zones of the digester.

1.Tempering system with heating pipes. There are two versions for execution:

- Polymeric heating pipes and reinforcement in the wall of a concrete digester (Fig.21).

Fig.21. Polymeric heating pipes and reinforcement in the wall

This version requires a very good external thermal insulation. Its advantage is that it does not cause sticking (surface "catch") of the substrate.

- Heating pipes of black steel in front of the digester wall (inside)

Fig.22. Heating pipes of black steel

The piping coil is installed on a metal bearing structure. In order to increase their operation life, the heating pipes can be manufactured by white steel V2A. The restrictions for internally installed heating pipes are connected mainly with overheating of the substrate near the pipes and possibility for deposition of biomass "rind" on their surface.

2.Tempering system with external heat exchangers (Fig.23)

The external heat exchangers have the advantage of being feasible and the surfaces, where the heat is exchanged can easily be cleaned. Pipe sectional and spiral heat exchangers are used, water-substrate type, in anti-current mode.

3. Biological heating system

The aerobic decomposition of the organic substances is accompanied by heat release. It can be utilized to increase the temperature of the liquid manure. For this purpose warm air is blown through. The biogas installation in Nordhausen heats 750 m3 of liquid manure up to working temperature of 330C in a digester with 400 m3 capacity on a daily basis.

Fig.23. External heat exchanger, type "spiral"

Stirring (mixing) systems

The stirring systems maintain the substrate in constant motion during retention and digestion in the methane tanks. In this way the thermal segregation of the biomass is avoided, which appears as a result of thermal loss, on the one side and, on the other – of overheating of the heating pipes surface. The fresh feedstock is mixed with the active manure and is contaminated with methane generating bacteria. When the substrate is in motion, the content of hydrogen ions becomes equal in the entire volume, which provides a steady pH in the digester. The stirring mechanisms agitate additionally the layers of solid mechanical particles, precipitated and floating on the surface.

Depending on the adopted principle for agitation and stirring of the substrate, the mixing systems are three types: mechanic, hydraulic and gas ejection ones.

- Mechanic stirring systems – these are the most popular mixing devices. Their major requirement is to provide uniform stirring of the substrate. Depending on the specific character of the feedstock biomass, the geometry of the tank and the structure of the stirring mechanism, the daily energy used in the form of electric current for stirring varies from 10 kWh to 100 kWh for digestion volume of 500-1000 m3.

In regards to the stirring intensity and energy consumption, there are 3 basic technological concepts.

- Very slowly moving stirring mechanisms, which with their shoulders and paddles encircle the whole digestion chamber and under constant operation mode possess very low single energy consumption. This group includes the versions with propeller stirring mechanism (Fig.24) and with blade stirring mechanism (Fig.25).

In both versions the rotation moment is transmitted from the motor by a reducer, located out of the digester. This solution affords stirring of substrates with large share of fibres and dry substance content up to 20% at excessively low energy consumption.

- Average quick stirrers with permanent operation or based on intervals, with average electric energy consumption. This version includes the rod mixing mechanisms with externally positioned motor (Fig.26).

Fig.25. Blade stirring mechanism

In both versions the rotation moment is transmitted from the motor by a reducer, located out of the digester. This solution affords stirring of substrates with large share of fibres and dry substance content up to 20% at excessively low energy consumption.

- Average quick stirrers with permanent operation or based on intervals, with average electric energy consumption. This version includes the rod mixing mechanisms with externally positioned motor (Fig.26).

Fig.26. Rod stirring mechanism with externally positioned motor

In these mixers the motor is positioned at the end of a long axis, on the other end of which a stirring blade is fixed. A flexible duct in the wall of the digestion tank allows to incline the axis in favourable (optimal) position. Cutting devices can be additionally installed on the axis or, small clicks can be welded to the propeller blade for additional fragmentation of the substrate.

- Quick intensively operating stirring systems with high electric energy consumption, switched on several times a day. This type of mixers involves the structures with electric motor, submersible in the substrate (Fig.27).

Fig.27. Stirring mechanism with submersible electric motor

The quickly moving propellers, connected without gear mechanism directly to the motor rotor shaft should not be operating on a non-stop basis, and by the help of a programmer they should be switched on for intervals of several minutes. Their energy consumption is large (kW in two-figure numbers) and their permanent operation can produce a considerable electric energy expense. Another restriction when using versions with submersible electric motor is the temperature operation of the digester. A mixing scheme with submersible motor is allowed in mesophilic operation. During thermophilic operation problems with overheating of the electric motor are encountered as a result of the disturbed heat abstraction from its body.

2. Hydraulic stirring system

Fig.28 presents a principle scheme of hydraulic stirring mechanism, rotating type (KTS).

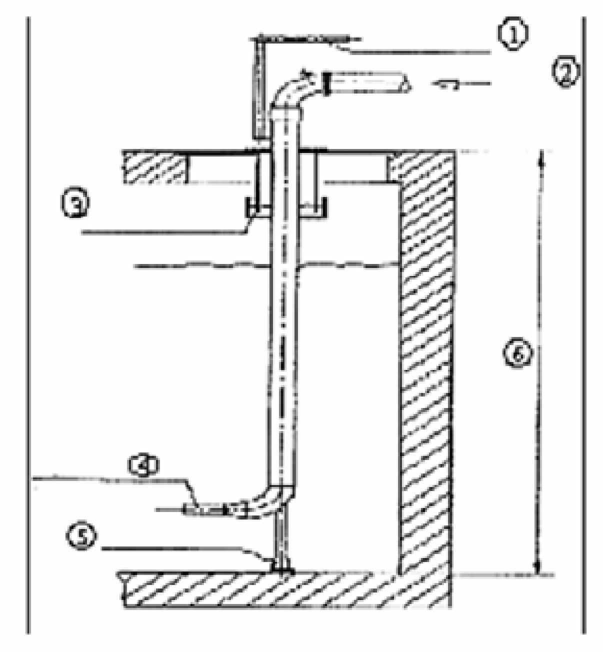


Fig. 28 Hydraulic stirring mechanism, rotating type (KTS)

Legend:
1. Engaging lever
2. Feeding (inlet)
3. Duct, gas-proof
4. Stirring nozzle, self-rotating, approximately 0-300°C
5. Main bearing
6. Digester wall

The driving section of the mechanism is a powerful central pump. It intakes substrate and injects it to the rotating nozzles. They push it under high pressure to the digester. By appropriate selection of a suction point and with injection points, controlled by rotating valves through the nozzles, good results can be achieved in mixing diluted fluids, which do not form layers.

3. Substrate mixing by the biogas pressure.

This mixing version is presented schematically in Fig.29.

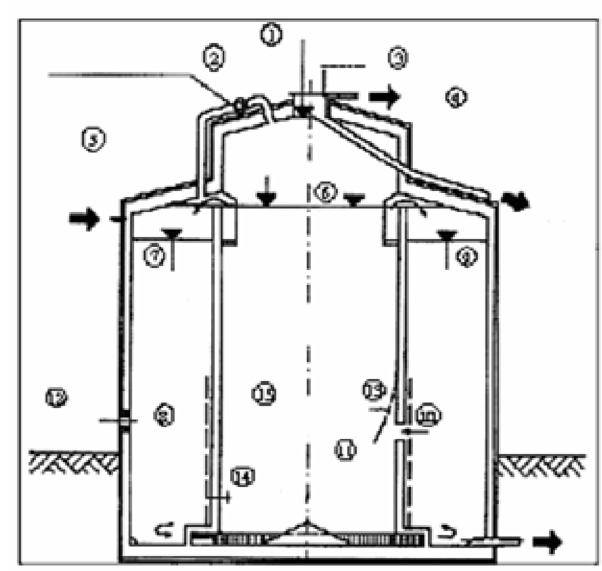


Fig. 29 Digester with substrate mixing by the gas pressure - VSP system

Legend:
1. Maximum uplifted level
2. Automatically controlled gas release (by electric manetic valve)
3. Gas dome
4. Gas
5. Feeding with influent (fresh substrate)
6. Level of equilibrium state (repose)
7. Pushed down level
8. Additional digestion chamber
9. Pushed down level
10. Discharge of digestive slurry (sludge)
11. Main digestion chamber
12. Trap door
13. Non-return valve
14. Heating block
15. Main digestion chamber

The choice of this mixing scheme should be well "weighted" at the design stage since it requires a more specific stereometry of the digester. The pressure of the biogas, accumulated in the digestion tank is used for ejection of the digested substrate, which passes through a narrow connecting pipeline in a compensating chamber. After opening the biogas discharge valve, under the hydrostatic pressure the liquid returns and is intensively mixed with the remaining part of the substrate. The main advantage of this mixing method is the absence of movable parts and the economy of electric energy for their driving.

A major restriction is the tendency to clogging of the overflow pipes. In this aspect the used substrates and the method of their initial handling should ensure elimination of any large solids and fiber components.

Pumping equipment

The pumping equipment is a mandatory part of the equipment completion of the biogas installations. The pump functions are connected with transportation, mixing, homogenization, and partial fragmentation of the substrate. Depending on the physical-chemical properties of the substrate, as well as on the overall technical-technological concept of the installation, several types of pumps find application.

1. Centrifugal pumps

They are used in the cases when large quantities of easily flowing (low viscosity) materials should be pumped out or agitated, with dry substance content below 8%. Basically the centrifugal pumps are not self-aspiring, therefore they should be either submersible or should be installed below the substrate level so that the liquid, which should be pumped out to be able to flow into the pump independently. When the operating wheel of the centrifugal pump is equipped with hardened knives, it is defined as a "cutting centrifugal pump".

The submersible centrifugal pumps can be installed so as one and the same pump to serve by choice either for mixing, or for substrate pumping out.

2. Volume and rotary pumps

Fig.30 shows a general view of a rotary pump

Fig.30. Rotary pump

The volume and rotary pumps are applied for agitation of thick materials that are often used in the biogas installations. The coferments and enzymes practically used are often delivered in paste form. In this aspect the volume pumps are irreplaceable. The volume pumps are self-aspiring, thus making the place of their installation relatively independent. Their structure allows reverse in the rotation direction. This allows the substrate to flow back and forth. During one rotor rotation, the volume pump ejects a precise quantity of material. In this way, by using a counter, reading the number of pump revolutions for one operation cycle, the quantity of the transported substrate can be determined. That is how the volume pump can be used as a dosing "unit" in the biogas installation.

Another advantage of the rotary pumps is the possibility to use them as a central pump, by the help of which to agitate all substrate fluxes in the installation from one point on. In this case it is necessary to use a gearbox for regulation of the driving torque according to the specific flux.

Distribution – control fittings

The control of the substrate fluxes and the processes, running in the biogas installations, require the construction of a central distribution unit for the substrate (Fig.31).

Fig.31. Central distribution unit for the substrate

Classification of the biogas installations

The different types of biogas installations can be conditionally divided into separate groups on the basis of some principle technical-technological criteria.

1. On the basis of the dry matter content in the substrate, the biogas installations are divided into two basic groups:

- biogas installations operating on the principle of methane digestion with liquid substrates (dry matter content below 30%). This group of biogas installations is very popular among the agricultural producers, entrepreneurs in the food and processing industry. It is suitable for all types of operations and activities, involving effluent waters, containing dry organic matter above 6%. Their operation principle is described above in Fig. 8 and Fig.9.
- biogas installations for solid domestic wastes. This group includes schemes for utilization of waste substrates, containing dry organic matter above 35%. They don't focus the attention of the agricultural producers and other

entrepreneurs. They require enormous investments and can be applied for creation of “manageable” waste depots around the municipal areas. They attract the attention for development of local, regional and national programs for utilization of communal wastes and for environmental protection.

2. On the basis of the charging regimen of the bio-digester, the biogas installations are sub-divided into:

- installations with periodic digester charging. Here it is relied on the technologically possible complete biomass digestion, after which the digester is discharged and charged again. This operation scheme is suitable for small biogas plants. Due to the low efficiency it doesn’t attract the interest of modern projects;
- installations with continuous (flow) digester charging and periodic bioslurry extraction. The larger part of the biogas installations, currently under construction, operate on this principle namely. They are characterized by high gas efficiency and uniform biogas feeding to the “consumer”. Their operation principle is presented in Fig.32.

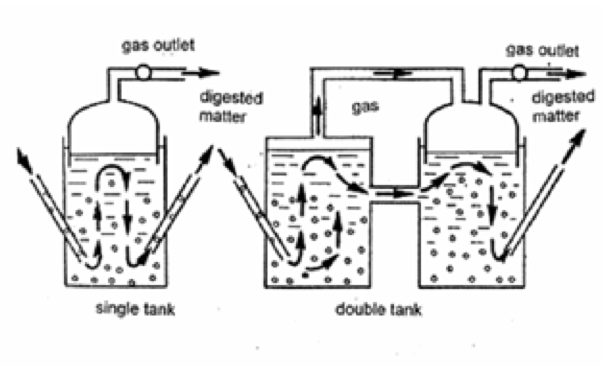


Fig 32. Method of continuous biogas production in vertical digester

3. very conditionally, the biogas installations can be classified into four groups according to the digester capacity:

- small – with useful digester capacity up to 150 m3;
- average – with digester capacity up to 500 m3;
- very large – with useful digester volume above 1500 m3;

4. Depending on the number of digester chambers, the biogas installations can be classified into:

- biogas installations with one digester

This type of installations is typical for the Asian and African biogas plants. Currently they are not very popular in the European countries. Their operation principle is based on the Schmidt-Egersglus method (the principle scheme is presented in Fig.33 and requires additional assembly of buffer tanks).

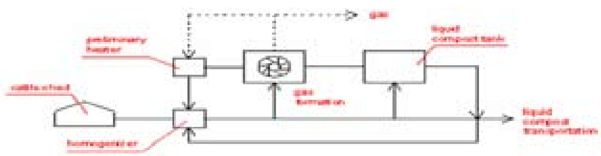


Fig. 33 echnologikal process by the Schmidt-Egersglus method

- biogas installations with two or more digesters

The principle scheme of this system is presented in Fig.34.

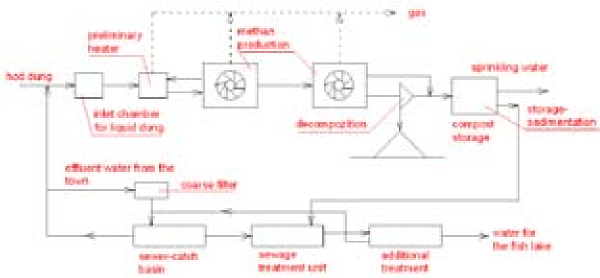


Fig. 34 Technologikal process for biogas production by two or more digesters (parallel or consecutively connected)

The sizes of the digestion chambers are determined by project-required technical and economic criteria. The main presumption of this type of biogas installations is to ensure uniform biogas production under reduced operation hazards, connected with occasional and abrupt deviations from the technological parameters of the chamber. With this system the digesters can be included parallel or consequentially. In the parallel inclusion, the whole process of methanogen dissociation runs in each of the digesters. The consequential inclusion of the chambers allows to delimit the acidic and methanogen phase. Technically, each of them runs in a separate chamber.

- biogas installations with replaceable digesters

This version of biogas installation presupposes parallel connection of two or more digesters. The presumption is to ensure technologically one digester in the phase of maximum methane production. At that moment the others can be in charge mode, in discharge mode or with other operation processes. This scheme guarantees uniform gas production with intensity, close to the maximum project parameters, yet it requires larger capital investments.

The biogas installations with two or more digesters require two separate schemes for microbial substrate dissociation.

- single-phase dissociation – all phases of the substrate mineralization run in one and the same chamber;

- bi-phase decomposition – it presupposes separate cycles of the acidic and methanogen phases in the time and space. Upon completion of the first phase, i.e. when the organic substances hydrolize and the material become liquid, it is transferred into another chamber for the methanogen phase. In this way the methanogen bacterial colonies are better preserved. The principal scheme of the bi-phase dissociation is presented in Fig.34, but it requires consequential connection of the two digesters. The separation of the substrate dissociation in two chambers allows more precise temperature control, pH control of the medium as well as C: N ratio control.

Systematization of the biogas installations according to the construction method

The construction solutions are various and comply with the conjuncture, yet on a general basis they can be reduced to two types:

- underground and semi-underground digesters – the construction of underground facilities ensures equal temperature regimen with comparatively low consumption of construction materials. This construction method is typical for small gas plants. It can be recommended for farms and plants with available premises for reconstruction or, when the characteristics of the terrain are suitable for a similar construction decision;

- ground-based installations – most of the newly-built biogas installations are built on the ground level. This decision is acceptable as a result of a number of advantages of the ready structures made by anti-corrosion processed metal or by polymers. With this type of equipment one of the basic project tasks is to take into account the heat loss through the walls of the digesters and to determine the necessary thermal insulation materials according to type and thickness. General view of a ground-based installation is presented on the photos in Fig.35 and Fig. 36.

Fig. 35 Overview of biogas facility with one digester (photo St. Stanev)

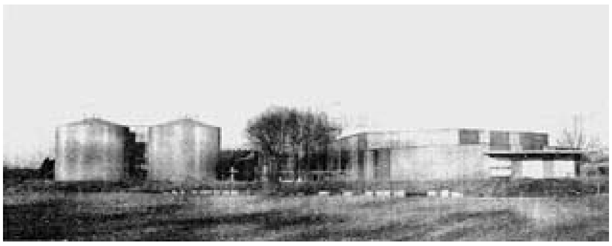


Fig. 36 Overview of biogas facility with two digesters (photo St. Stanev)

Another criterion for systematization of the biogas installations is the biogas storage method. In this aspect the facilities can be:

1. Installations with common digester and gas chamber. This solution is typical for small biogas plants. Since the produced biogas is stored in the digester (there is not a separate gas holder), its utilization should be continuous. The accumulation reserves are restricted and this often poses problems with the consumption regimen.

In this version for biogas storage a very suitable solution is to close the digester on the top by a polymer foil dome (Fig.37).

Fig.37. Foil dome on the gas storage digester

The foil is most often EPDM (ethylene-propylene-therpolymer) and is fixed on the edge of the tank wall by the Seeger method. In this case a conic channel of hard PVC is fixed by concrete to the top end of the digester wall. The foil is put in this channel and is sealed by a hose with air under pressure. Inside a wooden structure (type light farm) averts the dome hanging down in cases of insufficient internal gas pressure or rain and snowfalls. (Fig.38).

Fig.38. Wooden structure to avert dome hanging down

In order to avoid the placement of a bearing structure, the market offers inflatable covers of double foil. The space between the two foil layers is compressed to produce an air cushion with pressure of 20 to 30 barr. This solution stabilizes the dome against wind and rain and it is always cone-shaped, regardless of the accumulated biogas quantity.

2. Separately designed digester and gas chamber (gasholder).

With this type of installations, the biogas formed in the digester is fed to a separate gasholder. They are built near the digesters and represent metal tanks, plastic domes, plastic-skins, gas meters, etc. The basic advantage of this type of installations is the decreased content of water vapours and carbon dioxide in the biogas. In addition, the gasholder ensures constant gas pressure and consumption regimen according to the current energy needs.

Most biogas tanks are dimensioned so as to accept the gas output of minimum half a day. The large-scale farm biogas installations produce between 1000 and 6000 m3 biogas daily and the size of the tank should be calculated in compliance with this quantity. In order to avert failures and methane release in the atmosphere, the biogas installations with capacity above 20 m3/h should be equipped with emergency flame to burn the excessive quantity of biogas.

Due to price considerations, biogas tanks under pressure are no more applied in the field of agriculture. Their use is feasible only in connection with the biogas treatment.

The farm installations, most widely used as biogas tanks, are the drums of polymeric foil with different structures (Fig.39)

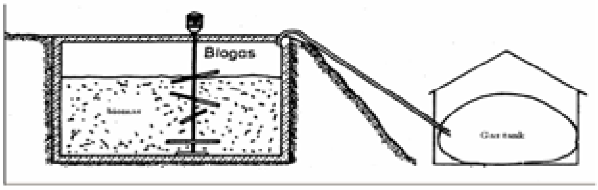


Fig.39. Gas tank of polymeric foil

The plastic is resistant to ultraviolet and other atmospheric effects. The foil is additionally "reinforced" by synthetic fibers, which improve the mechanic resistance of the tank. The gasholder can be installed both on an open site near the digester and in free production premises.

A version of the polymeric gas tank is the "tank-cushion" (Fig.40).

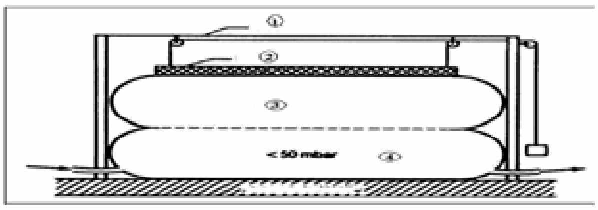


Fig. 40. Polymeric tank-cushion

Legend to Fig. 40.
1. cover;
2. loading weight;
3. gas storage cushion;
4. fundamental plate

This version of gas accumulation ensures constant tank pressure of about 50 mbar. This is achieved at the account of the weight, suspended upon the tank cushion.

Lately, the membrane gas tanks have become popular and they were the first to replace the wet gas meters, which were commonly spread some time ago. The tank body is cylinder or oval - shaped. It is a welded structure of sheet steel, in which a membrane serves to detach the changing gas chamber.

Systematization of the biogas installations according to the construction materials used

This classification is absolutely conditional since the selection of specific material is determined by many factors. Besides, for larger installations, it is completely normal to use different materials for construction of the separate elements of the facilities. Basically, the materials can be divided into 2 groups:

- traditional materials (stone, concrete, metal, reinforced concrete);
- new materials on the basis of artificial polymers (plastic, polypropylene, fibre-glass, polycarbon, polymer foil, etc.)

For small gas plants, the interest can be focused on rejected railway tanks, petrol barrels, plastic balloons, etc. The possibilities for their use, the insufficiencies and special features of the construction materials are enlisted in the table in Figure 41.

Construction material	Inlet storage facility	Digester	Outlet storage facility	Low-pressure gas tank
Reinforced concrete	■	■	■	▒
Concrete	■	▒	■	▒
Corrosion-resistant steel sheets	▒	■	■	■
Wooden material	□	▒	■	□
Glass-fibre consolidated polyester	▒	■	■	■
Heat-softening plastic	□	■	▒	▒
Plastic	□	▒	▒	■
Plastic boards	□	▒	■	▒

Fig.41. Construction materials for biogas installations

Legend:

■ Completely appropriate

▓ Appropriate to a certain extent

░ Inappropriate

Lately, there is a durable tendency to utilize synthetic polymeric materials since their advantages, such as lightness, low cost, anti-corrosion, low thermal conductivity coefficient, etc. are beyond any dispute as compared to the traditional construction materials.

Conclusions concerning the classification of the biogas installations

The practical operation of the separate types of biogas installations for liquid substrates imposes the following essential conclusions:

1. According to the quantity of product and the level of gas extraction the step-like and the flow-type system do not differ substantially;

2. The method of the step-like system should be preferred in the following cases:

- if the organic material to be treated appears periodically and in large quantities;
- if the share of cellulose in the organic material for gas processing is large (for example, straw and stalks);

- if, under certain circumstances, it is necessary the step-like designed and built installation to pass to technological regimen of flow-type production.

3. The method of the flow-type biogas system requires lower construction expenses and the operation runs with less manual labour.

4. The selection of horizontal or vertical disposition of the equipment (most of all the digesters) depends on the specific character of the ground terrain, the level of underground waters as well as on the nature of excavation works.

5. In cases of high underground water, the horizontal disposition of the installation is recommended;

6. The horizontal design is also suitable for chambers with capacity above 15 m3.

7. In areas with lower temperatures, the digester should be manufactured with double walls and thermal insulation. In these cases, the gas meter floats on the water "pillow" between the two walls. Thus, the gas dome will not be polluted by the liquid dung and the corrosion will be avoided.

8. The research on the diffuse gas extraction shows that the liquid dung in the first phase (in the first room of the operation chamber or the tank) should be retained longer (twice more) than in the second phase. The volume of the main (primary) digester should be twice as large as the secondary one. In this case the submerged ends of the gas meter, built above the secondary digester, remain clean. The primary digester should be equipped with a stirrer. The gas discharge units should be fixed on the highest point of the digester.

9. Combined (joined) construction digester-gasholder is recommended for areas with cool climate since the metal gas meter cools the digester very strongly. The insufficiency of this method is the unequal gas pressure.

10. The smaller biogas facilities should be built in such a way as the digester chamber to occupy one and the same space. In this way the construction costs of the hanging metal dome will be reduced, the thermal loss will be increased and hence – the total installation efficiency.

11. In larger facilities it is advisory to separate the gas extraction phase from its storage. In this way the thermal loss by the metal gas holder will be decreased. The gas meter floats in water (liquid), therefore the gas pressure remains constant.

12. The biogas facilities should not be penetrated by effluent waters from bathrooms or laundries, polluted with soaps or other detergents. The faeces-polluted waters should be fed into the biogas digesters separately.

13. The attempts to utilize the organic bioslurry material for forage show that a mixture of 10% bioslurry with rough forage is well assimilated. The biomaterial is supplied for cattle food after a slight humidification.

What are the most frequent failures and defects of the biogas installations for liquid substrates

1. Gas loss appears:

- in cases of insufficient gas compression (walls, roofs, soil, etc.);
- in cases of insufficient sealing of the bearing hoops of the gas holder, built above the digester, above the compost depot, etc.
- in cases of low air-tightness in the gas-pipe system;

2. Thermal loss occurs:

- in cases of insufficient thermal insulation or when hygroscopic materials are used;
- in cases of bad insulation of the gas holder;
- when heat is released through the inspection entrances, the mixing units, the input and output pipes.
- in re-designed or not well insulated heating pipes;
- in cases of frequent discharge of the liquid compost

3. Failures occur most often upon:

- material condensation – the reasons are incorrect or insufficient operation of the mixing unit, or inappropriately selected replacement method, the small pipe cross-sections, the constant overfilling of the digester, the solidification of the pulp on the surface of the liquid, etc.
- incorrectly sized and selected charge pumps (with lower operating parameters);
- admission of disinfectants, detergents or other chemically active substances with bacteriostatic or bactericidal effect;
- cooling and freezing of the input-output pipes for dung and gas or, silting of the pressure valves;
- solidification of the pulp in the digester as a result of irregular cleaning, according of the project technological scheme.

Method of biogas production by solid domestic wastes (SDW)

The domestic wastes from the municipalities are rich in dry organic matter. Usually their humidity is lower than 70%, which basically doesn't allow application of the liquid-substrate digestion technologies (examined so far) and the biogas production.

The suitable SDW digging evokes anaerobic dissociation similar to that in the digesters and the composition of the obtained biogas is also similar: methane 55-70%, carbon dioxide 30-40%, and small quantities of trace amounts. Its caloricity is about 26 MJ/m3.

Basically, the production technologies on SDW basis are presented schematically in Fig.42.

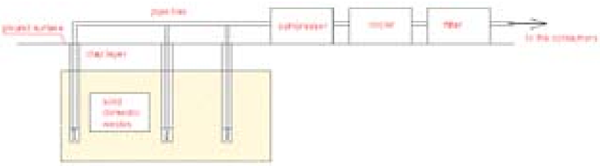


Fig. 42 Principal scheme for biogas production by solid domestic waste

The garbage is buried under the surface in a thick layer. It is covered with soil or plastic foil. Clay "sealing" is made on top with thickness of about 1 m.

After being generated in the "body" of the dumpsite, the biogas moves in the following ways:

- diffusion – the gases in the dump site move from places with high concentration to places with low concentrtion;

- convection – the gases, accumulated in the garbage create areas with higher pressure and move towards the surface;
- solubility – the methane is soluble in water and can be released in small quantities by the obtained infiltrate.

The biogas generation and moving is favoured by a slight temperature increase in "the body" of the dumpsite (in the summer months) and moisture content of 40-50%. The relative methane share in the biogas begins to increase only when the quantity of oxygen in the buried garbage is exhausted and drops down below 2%.

As the methane content in the biogas depends on the composition of the buried wastes, before the implementation of each specific project it is necessary to make a check whether the biogas production will be profitable. This is done by several sample soundings and within 3-4 months' period a "pumping" test is carried out to determine the biogas content as a function of:

1. The pumping level of the soundings;
2. The flow rate as a function of the pressure decrease during pumping;
3. The impact zone of the pumping soundings.

For this purpose several vertical openings are made in the buried waste. Several PVC pipes are inserted into them (Fig.42), the upper ends of which are connected to a common central collector by appropriate adhesives (for example, bentonite glue). When the tests yield positive results, the number and location of the operation soundings can be determined as well as the most suitable configuration of the collector system.

The quantity of generated biogas is usually largest in the first few years after SDW burying and with the time it decreases by an exponential dependence with the respective semi-period. The dependence is graphically presented in Fig.43.

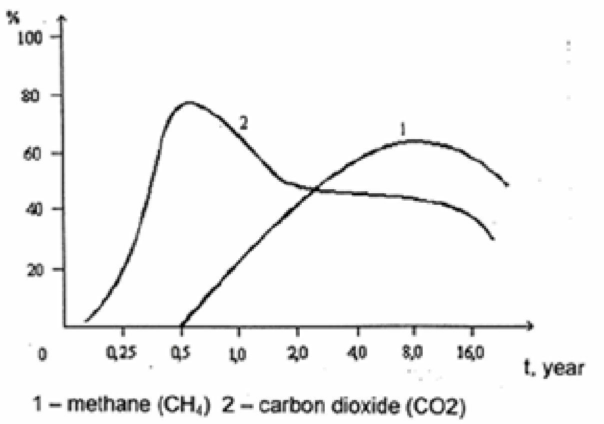


Fig. 43 Temporal change of the composition of biogas, produced by SDW

The biogas produced by the collector system is subject to treatment before its delivery for burning. The principal scheme of the biogas treatment is shown in Fig.44.

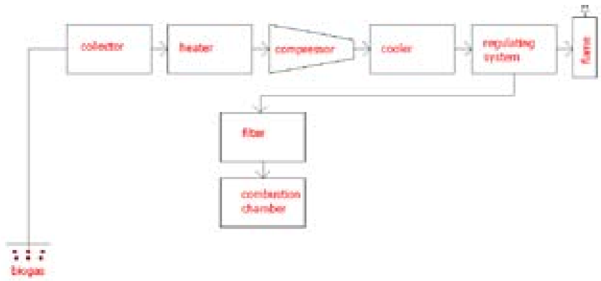


Fig. 44 Block-scheme for dung-hill gas treatment before burning

The biogas should be heated from temperature of 3030K (300C) up to 353-3630K (80-900C) for moisture release. The dehydrated gas is fed by a compressor for cooling down to temperature of 2770K (40C). The cooled gas pressure is monitored by a control system as part of the gas is burnt in the atmosphere (open torch system). The biogas is discharged for burning through a filter for separation of particles, larger than 0,3 mm.

The biogas production method by SDW requires enormous areas and investments. In this sense it is not "attractive" for private undertakings of separate farmers and entrepreneurs. This method is interesting for regional projects, different in scale, which are controlled by state, branch or other type of entities.

How to utilize the obtained biogas

Direct burning

The most simplified scheme of biogas utilization is its direct burning by a torch, fixed on a boiler or a furnace. The advantage of this version is primarily in the low requirements to the biogas purification. The burning installation is cheap and feasible.

The direct biogas burning is applied mainly in the warm-water production in boilers for residential buildings heating, greenhouse heating, or for other processes. The biogas burning in furnaces allows to ensure energy for operations, requiring enormous thermal energy (production of bricks, cement, glass, and many others).

The direct biogas utilization requires very precise design and trade off between the technological regimens of the biogas installation, on the one side, and the fuel installation and the thermal energy consumers, on the other side.

Co-generation or combined production of electric energy and heat

The main condition for co-generative production of electricity is to ensure thermal energy consumers. In this way the power efficiency of the entire facility will be increased. The energy conception of the co-generation is presented best by the following example: with state-of-the-art power stations the coefficient of performance reaches up to 42%. The remainder of the fuel energy is let out with the air through the cooling towers. The combined production of electricity and heat increases twice the efficiency of the initial fuel energy utilization and the values of the coefficient of performance for the co-generative module are within the range 77-78%, as the electric/thermal energy ratio is about 1÷1,5.

Main parts and overview of the co-generation facilities

The co-generative unit includes an electric power generator, which is usually driven by a fuel motor (internal combustion motor – ICM) and heat exchangers for utilization of the motor heat (Fig.45).

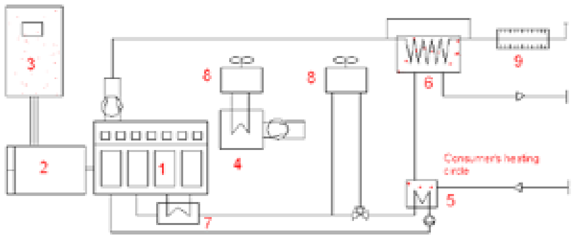


Fig. 45. Block-scheme of co-generation unit

1. Gas motor
2. Generator
3. Distributor with control system
4. Intermediate cooler for filling mixture
5. Heat exchanger water/water
6. Heat exchanger flue gases/water
7. Lubrication oil cooler
8. Radiator cooler
9. Muffler

Fig. 45. Block-scheme of co-generation unit

That heat is let out at two temperature levels. The heat exchangers of the aggregate unit and the lubrication motor system ensure utilization of the thermal energy at level of 80-900C. The other heat exchanger acquires heat from the outlet flue gases with temperature of 400-5000C. With regards to the thermal carrier flow, the heat exchangers are consecutively connected. Usually the co-generating units are designed for supply of heat to heat-conducting systems of 90/700C and less to systems of 110/850C or 130/900C.

Within the power range from 20 kW to 5000 kW, basically ignition fuel motors are used. These are motors operating on different principles: methane-diesel, pure gas ones with spark plugs for ignition of the methane air mixture, etc.

For higher power up to 200MW, co-generating units are offered with gas turbines. The biogas to drive the turbine should be let in with pressure of 1,5-2,5 MPa, depending on its compressing effect. The flue gases are discharged from the turbine to the boiler (heat exchanger) for production of heat in the form of water vapour or hot water.

A basic index for the investment expenses in combined production of heat and electricity is the specific investment cost per installed electric power (EUR/kWe*). This value moves within the limits from 320 to 1270 EUR per 1 kWe and usually decreases with the increase of the installed power (without construction expenses and the costs of the electric and thermal energy discharge from the unit).

KWe* - kilowatt electric power

Tri-generation

The co-generative production of electric energy and heat arises the question how to utilize the thermal energy in the summer months. The solution is only one – transformation of the thermal energy into cooling energy by using absorption refrigerators. By this scheme the conversion of the biogas energy is tri-generative:

The refrigerating energy during tri-generation is at temperature level about +50C, which is very suitable for entire air-conditioning of hotel complexes, hospitals, production operations or for construction of high-temperature refrigerating chambers and dryers.

Biogas enrichment

Biogas enrichment facilities have been built in the USA, the Netherlands, Sweden, Germany. The systems for biogas purification and enrichment require complete desulfurization and methane-gas concentration above 99%. The technologies for methane and carbon dioxide separation are based on methods of chemical absorption, membrane separation and cryotechnological treatment. The purified methane-gas is compressed under high pressure and is used for transport needs.

In this aspect the example of Sweden is very indicative where under the monitoring of the national and local management structures the purified methane-gas is used as a fuel in the municipal automobile transport. Besides, the first ecological train in the world has been designed, which is driven by purified and enriched biogas. The motor-coach engine is with two diesel engines (reconstructed for operation with methane) and the capacity is 54 passengers. Its maximum velocity is 130 km/h and one charge ensures a 600 km run.

It is obvious that one of the main directions of the future power industry is the improvement and wider introduction of the methods for biogas production and utilization. The progress in this aspect is a step ahead in overcoming the power crisis and a basic model for health and environmental preservation of our planet.

A model for economic analysis of agricultural biogas installation

Factors of the economic result

The economic evaluation of a given biogas installation during the design stage possesses complex character and is determined by many factors. Some of these factors are connected with technical-technological solutions, which are the basis for the installation construction and equipment. Here belong the construction expenses, the cost of machines and units for substrate processing and transportation, devices for automatic control, monitoring and signaling of the separate processes as well as protection reinforcement against explosions, fire and environmental pollution. These "direct" costs involve also the funds, necessary for equal substrate (biomass) feeding into the facility. Major importance for the final financial results is attributed to the real and long-term prognosis of what part of the substrate the entrepreneur will produce himself and what will be the share of biomass and co-ferments, externally delivered.

Another group of factors, which determine the economic profile of a given biogas installation, is connected with the design, construction and operation management. The evaluation (especially in long-term aspect) of the incurred expenses is very difficult, since the impact of these factors depends on the conjuncture, the dynamics of the energy market, the statutory involvement of the state, the branch and public organizations, the bank policy, etc.

An exemplary scheme of expenses for a biogas installation management in the process of design, legalization and commissioning, should take into consideration the following:

- Project funding – sources, settlement schedule, credit terms and conditions and, interest rate;
- Design and legalization – expenses for technical-technologic and engineering-construction design. Binding the project with the legislation, operating in the country and the region.
- Project approval and certification – expenses for the respective licensing regimen in the country, ecological license for environmentally admissible emissions;
- Company establishment (body corporate) and all connected expenses; state and local charges, lawyer's and consultant's fees;
- Qualification of the entrepreneur and (or) persons who will operate the biogas installation;
- Development of a discharge scheme for the digested substrate and utilization of the matured bioslurry;
- Current power feeding – expenses for combustion fuel (for example, diesel fuel), heat for the digester temperature maintenance, electric energy for the installation units (macerators, transporters, mixers, etc.)
- Labour cost;
- Rent of machines and equipment – periodic expenses, connected mostly with co-ferment processing, etc.
- Service maintenance and operation repairs;
- Current qualification – allocation of funds for special literature and information, membership in editions and information, affiliation in associations, etc.
- Expenses for public work – organization of events of the type "open doors", sharing of "good production practices", etc.
- Periodical analyses – funds, covering expenses for laboratory chemical and microbiological analyses of the digested and discharged substrate. Control of the heavy metals content and pathogenic microflora in the bioslurry, discharged from the digester.
- Insurance of the entity (the biogas plant) – expenses for annual insurances or insurances with another term, statutory regulated, required by the banks or demanded by the entrepreneur;
- Entrepreneur risk – the experience and analysis of the biogas installations operation in Germany, Dane, Sweden, etc. have shown the need to calculate the so-called investment risk. It is recommended to be minimum 2% annually of the investment overall cost;

Taking into consideration the mentioned factors of the economic result and the subsequently incurred real expenses, a summarized economic account can be made of a biogas installation with co-generative unit for electric energy and heat under the following parameters:

Economic parameters for a biogas installation in design stage

1. Investment for the digester, 30 % of which for servicing equipment (transporters, macerators, lamps, etc.) - 250 €/m3
2. Investment for a co-generative block (for production of electric energy and heat) 20 % of which for security devices; 10 % for signaling fittings, 10 % for combustion liquid and other fuel and lubricator consumptives at fixed price (0,38 €/l) - 450 €/kW
3. Investment for dung site - 41 €/m3
4. Own consumption of electric energy (electric motors of the macerator, mixers, transporters) - 10,1 Ct/kWh
5. Unexpected and alternating energy expenses 1,5 Ct/kWh
6. Transport cost and expenses for substrate processing - 1,8 €/t
7. Interest - 6 %
8. Digestion time - 40 – 50 days
9. Maximum content of dry substance in the substrate - 20 %
10. Annual loading (motor hours) of the co-generative unit (h/a – hours per unit) - 8000 h/a
11. Efficiency coefficient of the electric generator - 22 %
12. Duration of the waste dung mass (bioslurry) storage - 180 days
13. Evaluation of the bioslurry mineral content
    - N (Nitrogen) price - 56 Ct/kg
    - P_2O_5 (Phosphoric oxide) - 55 Ct/ kg
    - K_2O (Potassium oxide) - 28 Ct/kg

In accordance with the specified parameters, the natural biogas product and the financial receipts of using liquid dung from cattle breeding operations possesses approximately the following structure:

Substrate	Dimension	Cow dung	Pig dung	Poultry dung
Fresh mass (FM)	T	1	1	1
Dry substance (DS)	%	8,5	6,0	15,0
Organic mass of the dry substance	%	85	85	75
Gas yield by the dry substance	l/kgTS	280	400	500
Gas yield by the fresh mass	M3/tFM	20,2	20,4	56,3
Methane content	%	55	60	65
Electric energy yield	kWhe/t	39,6	43,5	130
Receipts	€/tFM	4,0	4,40	13,13

The practices of the agricultural biogas installations have explicitly proven that the biogas production only by liquid dung in not profitable. The main reason is the relatively low gas yield of the substrate. In this aspect the combination of liquid dung with other co-ferments is a mandatory condition for a better financial result. Very good indices of gas output are characteristic for the green and forage cultures, planted especially as a potential biomass or, being waste of other technological processes. The next table presents in a summary the natural and financial receipts of the farm cultures, most recommendable for biomass.

Substrate	Content Dimension	Meadow grass, beginning of blooming	Silage grasses, medium stage of blooming	Maize silage, milk-wax ripe-ness	Forage beet	Wheat grain
Fresh mass FM	T	1	1	1	1	
Dry substance of TS	%	20	35	35	16	87
Organic dry substance of TS	%	90,8	89,8	96,0	90,3	98,1
Gas output	l/kgTS	548,5	561,6	599,6	683,9	700,9
	m3/tFM	99,6	176,5	201,5	98,8	598,2
Methane content in the biogas	%	53,8	53,6	52,3	51,1	52,8
Electric energy yield	kWhe/tFM	190,4	336,5	374,6	179,6	1123,3
Financial re-ceipts	€/tFM	19,2	34,0	37,8	18,1	113,5

An exemplary calculation of a final financial result for a biogas installation

On the basis of the overall investment and other expenses as well as of the expected receipts from the biogas production, we'll present an exemplary calculation of the final financial result for a biogas installation with a co-generative unit (20 kW).

Part: Natural and financial receipts

1. Annual gas output by digestive dung with useful volume 481 m3, digestion time of 50 days, biomass of liquid cattle dung and maize silage - 75 748 m3
2. Energy obtained by the co-generative unit for 8000 working hours annually (expected downtime of 5-7 days for current maintenance) - 406 652 kWh
3. Energy obtained at the account of the combustion fuel, necessary for the motor operation - 45 184 kWh
4. Gross energy obtained by the co-generative module (amount in point 2 and point 3) - 451 836 kWh
5. Share of the produced heat energy out of the gross energy 50 % (point 4 x 50 %) - 225 918 kWh
6. Heat energy consumption for maintenance of the digester temperature - 122 683 kWh
7. Saved thermal energy for domestic heating and production of hot domestic or technological water (point 5 – point 6) - 103 235 kWh
8. Electric energy, actually obtained with efficiency coefficient of the electric generator of 29% (point 4 x 29%) -131 032 kWhC
9. Annual financial receipt from the obtained domestic heat and the produced domestic and technological hot water (point 7, expressed in value) - 1 553 €
10. Annual financial receipt from the electric energy, produced by the co-generator at average market price of 10,10 Ct/kWh (point 8 x 10,10) - 13 234 €

11. Annual gross financial receipt from the production of thermal and electric energy from biogas (the sum of point 9 + point 10) for one year - 14 787 €

Part: Financial expenses

12. Amount of the investment expenses for digester with volume 481 m3 with calculation for a single construction and technical expense - 250 € /m3
13. Investment expense for co-generative unit 20 kW with operation life of 5 years - 6 000 €
14. Gross investment expense (point 12 + point 13) - 126 277 €

15. Annual depreciations of:

the biogas installation: construction part (70% with 20 years' depreciation period) - 4 210 €

- technical-technological equipment (30% with 10 years' depreciation period) - 3 608 €

16. Annual depreciation allowance for the co-generative unit at 5 years' depreciation period - 1 200 €
17. Annual interest on the investment capital – 6 % - 3 788 €
18. Annual amount of the mandatory insurances and social benefits 0,5 % - 601 €
19. Annual expenses for service maintenance:
    - construction part – 1 % - 842 €
    - technical part – 3 % - 1 082 €
    - co-generative unit – 10 % 600 €
20. Labour cost for control and operation of the installation, 200 hours average annually at rate of 15€/h - 3 000 €
21. Annual cost of the combustion fuel (for example, diesel fuel) 4 518 l x 0,38 €/ l 1 717 €
22. Annual cost of the electric energy consumption of the installation 25 124 kWh x 9,0 Ct/kWh (the price is preferential) - 2 261
23. Total for the facility, realized annual expenses (the amount of the expenses from point 12 to point 22) - 22 910 €
24. FINAL FINANCIAL RESULT FOR THE ENTR PRENEUR (the difference of point 11 – point 23) - 8 123 €

When reducing the initial single investment for the digester of 250 €/m3 to 150 €/m3, the financial loss in point 24 of the presented calculations will drop to – 2 543 €. The decrease of the single investment is connected with the choice of technical equipment of lower class, thus lowering the automatic control level in all stages of the production processes.

The presented financial calculations and the practice of the biogas plants in general show that without adequate legislation and state financial policy for promotion of alternative energy sources, the development of the biogas power engineering will loose its sense.

One of the main factors for the vigorous advance of the biogas method in Germany is the legislative policy for encouragement and funding of biogas projects. The Law for renewable energy sources (EEG) determines adequate statutory medium for development of programs, stimulating the economic initiative in the area of biogas production. Currently in Germany there are two large-scale operating programs for stimulation of biogas projects. The MAP Program involves four different versions for direct and indirect financial stimulation.

The agrarian investment program envisages 9 different stimulation versions. Depending on the selected preferential regimen and the applied criteria, the entrepreneurs can use financial stimuli at amount, reaching 40 % of the gross investment cost.

In this sense the future development of the biogas power engineering will be determined by the technical-technological progress as well as by the adequate legislation both of the separate countries and the European Union as a whole.

Examination of biogas installations

Biogas installation SCHMITZ in Aschendorf

Customer: Mr. Georg Schmitz, Tel.: 04968 – 201
Am Seitenkanal 3
26871 Aschendorf - Papenburg
Designer/ Manufacturer: Krieg & Fischer Ingenieure GmbH, Tel. 0551 – 3791386
Hannah-Vogt-Straße 1, Fax: 0551 - 7707712
37085 Göttingen info@kriegfischer.de
www.KriegFischer.de

Fig. 46: Biogas installation SCHMITZ (Aschendorf)

Mr. Georg Schmitz's biogas installation is located in Papenburg/Aschendorfermoor in immediate proximity to his farm plant. Its construction began in 2002 and in the beginning of 2003 the installation was commissioned by Krieg & Fischer Ingenieure GmbH. Mr. Schmitz feeds his biogas installation with about 3,000 cubic meters of pig dung annually and about 700 cubic meters primarily of vegetable oils. The dung is supplied partially from his fattening pigsty as he additionally delivers pig dung from other agricultural plants in the region.

The dung and oils for mixing and intermediate storage are collected in a covered pit. Then they are pumped out to the hygienization tank (decontamination, disinfection). The hygienisation at temperature of 700C is necessary to exterminate the microbes and bacteria and to avert their penetration in the circulation circle. What is more, the feedstock is better dissolved as the preliminary hygienisation decreases the hydraulic return time as well.

A technological feature of Mr. Schmitz's installation is that it involves equipment, completely complying with the process. The digester whose volume is about 450 cubic meters, is stirred – similarly to the industrial installations – by means of a mixing mechanism, installed on the top side, with externally positioned motor. The tank is made of reinforced concrete.

The digestion process is carried out in thermophilic environment within temperature range between 50 and 550C. The produced biogas passes from the digester to the gasholder of the tank for additional digestion, whose capacity is about 1700 cub. m. Thanks to the double membrane of the dome-gas holder, the negative atmospheric effect is avoided. The airtight cover doesn't allow release of any odorous emissions.

The produced biogas is burnt by two gas Otto-motors with electric power of about 100 and 70 kW, respectively. These motors burn biogas and provide compliance with the statutory requirements for air pollutants' ejection. When necessary, natural gas can also be used.

Fig. 47: Digester and additional digester of biogas installation in Körber-Harriehausen

The concept is based on the idea of Prof. Konrad Scheffer from the Institute for useful plants at the Kassel/Witzenhausen University. The funding has been made by means of a considerable subsidy from Dr.Volker-Reimann-Dubber's Foundation. The biogas installation was built in the period from the autumn of 2002 until the spring of 2003 by Krieg & Fischer Ingenieure GmbH. The commissioning was in March 2003.

Biogas installation DAMMANN in Harsefeld - Issendorf

Customer: Mr. Friedrich Dammann, Tel.: 04163 – 811 471
Horneburger Strasse 21; Fax: 04163 – 811 473
21698 Harsefeld-Issendorf
Designer/ Manufacturer: E.U.R.O. Biogas, Contact person: Mr. Sven Nölter, Dipl.Eng.
Anlagenbau GmbH, Tel. : 0 51 93 / 97 44 85
Hasweder Weg 2, Fax : 0 51 93 / 97 44 86
29640 Schneverdingen, e-mail : info@eurobiogas.de

Description of the installation:

Fig. 48: Concrete digester with mixing mechanism with longitudinalshaft with externally positioned motor and gear-box

The biogas installation is located in the yard of Mr. Friedrich Dammann's farm plant, immediately in the central part of Harsefeld-Issendorf. The construction of the installation began in October 2001. It was as early as in the end of December 2001 that the first current was produced. The overall construction, including the required acceptance and approval, was completed in June 2002.

The biogas installation consists of digesters and residual-digestion store made of reinforced concrete, round tank with concrete roof, machine premise, technical premise and gas-holder for low-pressure gas, executed as foil reservoir, central pump-distribution station, solid substances charging unit, consisting of reserve bunker with sliding floor, rod conveyor and piston, block thermal power stations and central operation control unit.

The installation operates almost completely automatically, the digester feeding with fresh substrate and manure is automated as well as the pumping of the digestion remains out to the residual digestion store.

Remote control of the installation has been developed and is ready to start operating any moment by using a PC with the respective visualization of the installation and the necessary software.

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BIOFUELS

Introduction

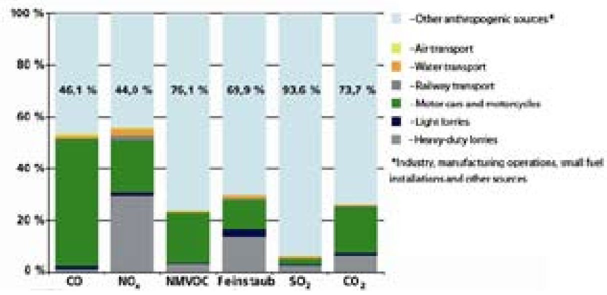

Fig. 1: Share of transport emissions in total anthropogenic related emissions– based on data from Baden-Württemberg (Source: UMEG/AVISO 2003)

Transport vehicles are the cause of as much emissions as no other human activity. In Fig. 1 are shown the shares by per cent of the six most significant hazardous substances of carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (NMVOC, non methane volatile organic compounds), particulate matter, sulphur dioxide (SO2) and carbon dioxide (CO2) in the total emissions from passenger and cargo transportation in the province of Baden-Württemberg. In the average, one third of the emissions of these hazardous substances is attributed to transportation traffic, and more than the half are emissions of CO and NOx. The next are particulate matter, CO2 and NMVOC, the lowest share being this of SO2.

Most of the hazardous substances linked to vehicle traffic are attributed to automobile cars and motor cycles, that is, privately owned vehicles. And the highest portion of CO, CO2 and NMVOC vehicle traffic emissions is attributed to privately owned vehicles. Heavy motor vehicles are the main source of NOx and particulate matter. Participation of railway, water and air transport in emissions of the hazardous substances reviewed is comparatively insignificant. These data can be different from data obtained from other federal provinces, as well as the average values for Germany. However, no significant deviations can be expected.

It is known that the world's crude oil resources are finite and the time of their depletion depends on many factors. Timing of depletion of fossil energy reserves depends among other things on world consumption of primary energy and the mix of primary energies. The more the predominant consumption of non-renewable resources is increased, the more earlier the world's crude oil resources will be depleted.

As presently fuels are still almost completely produced from crude petroleum and environmental problems are on the increase, there is a need to create alternatives to fossil based fuels that will be environment-friendly. Unquestionably, among such alternatives are biofuels based on plant oils, cereals, wood and other renewable raw products which can contribute to the achievement of a permanent flexibility.

A look at the spectrum of the biofuels (Fig. 2) shows that there is something for any type of engine, even if technical conditions are not present for all individual cases.

Plant oil based fuels	Bioethanol	Biogenic gases	SynFuels	Hydrogen
Oil crops - rapeseed - sunflower - Camelina sativa (false flax), etc. - biodiesel - natural plant oils	Renewable raw materials - cereals - sugar beet - potatoes - others - ethanol - ethanol-petrol blends	Biogas from fermentation and thermochemical conversion into gas of renewable raw materials and biogenic waste - biogas - gas from waste treatment plants - methane containing gas as substitute of natural gas	Conversion of renewable raw materials and biogenic waste into gas - wood - straw - fermentation remains - biomass - gaseous, methane containing SynFuels as substitute of natural gas - liquefied SynFuels as substitute of petrol and diesel - methanol	Hydrogen from biomass through thermochemical and microbiological processes - Hydrogen as a long-term fuel, particularly for electrochemical generators

Fig. 2: Overview of the spectrum of biofuels

Plant oil-based fuels

The main representative of plant oil-based fuels is the so-called biodiesel. It is a chemically improved natural plant oil of properties very close to these of the conventional diesel fuel. With appropriate modifications of the engine and fuel system the natural plant oils can be used also for diesel engines. Plant oil-based fuels are produced mostly from rapeseed, but sunflower and false flax (Camelina sativa) are also being used.

Bioethanol

The ethanol alcohol can be used in Otto engines. It is produced by fermentation of sugar and stark containing crops such as cereals, sugar beet, potatoes, etc. Combustion of bioethanol is significantly a cleaner process as compared to petrol or diesel fuel.

Biogases

Biogenic alternatives of natural gas are also available for gas engines. Biogas contains methane and can be recovered in biological treatment systems by fermentation or thermo-chemical gas generation and then used in conventional engines.

State	2003	2004	Growth
Germany	715000	1035000	+44.8%
France	357000	348000	-2.5%
Italy	273000	320000	+17.2%
Denmark	41000	70000	+70.7%
Czech Republic	70000	60000	-14.3%
Austria	32000	57000	+78.1%
Slovakia	0	15000	0.0%
Spain	6000	13000	+116.7%
Great Britain	9000	9000	0.0%
Lithuania	0	5000	0.0%
Sweden	1000	1400	+40.0%
Total EU 25	1504000	1933400	1933400

Synthetic fuels (synfuels)

The name synfuels (known also as BTL(Biomass-To-Liquids)-fuels) is used to denote artificially-produced hydrocarbons. For this purpose, biogas is dissociated into carbon monoxide (CO) and hydrogen (H2) which are then combined in hydrocarbon chains by the Fischer-Tropsch synthesis process. A final hydro-enrichment process changes length and form of molecules so as to obtain a fuel optimally suitable for the engine. Synthetic biofuels can replace both petrol and diesel fuel, and natural gas.

Use of biofuels in Europe

The European Union produced almost 2.5 million tonnes of biofuels in 2004 which compared to the approximately 2 million tonnes in 2003 (inclusive of the new member states) represents an increase by 25.7 %.

Biofuels can be divided in various groups: bioethanol, plant oil-based fuels (biodiesel) and natural plant oil-based - biogas, biomethanol, biodimethylether, bio-ETBE (ethyl-tertio-butyl-ether), synfuels and biohydrogen. Among these, biodiesel and bioethanol play the most important role.

Biodiesel

The European Union is a world leader in the biodiesel fuel sector. In 2004 eleven states participated in the biodiesel production, inclusive of the new EU member states (Czech Republic, Slovakia and Lithuania). The increasing importance of biodiesel is clearly seen from Fig. 3 showing European biodiesel production since 1992.

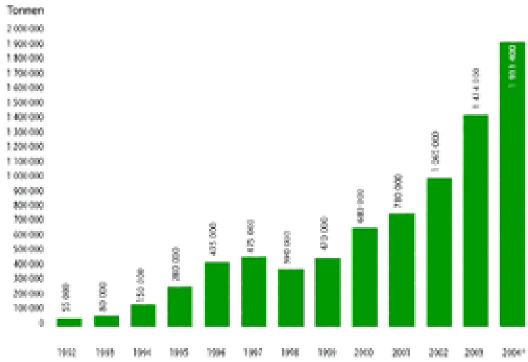

Fig 3. Production of biodiesel fuel in the EU as from 1992

Indeed, these quantities are rather distant from the actual production capacities evaluated at 2.4 million tonnes for 2004 by EEB (European Biodiesel Board).

In 2004 Germany again defended its position as the leading European biodiesel producer. For the first time production has exceeded the one million tonne mark (1,035,000 tonnes) which is an increase by 44.8 % as compared to the previous year. The biodiesel produced by Germany accounts for more than a half of the European production. This success is mainly due to the exceptionally favourable legislation. As from 1 January 2004 biogenic ingredients in fuel mixes are also exempted from the fossil oil tax (tax exemption for biofuels is in effect as early as 2002). In addition, biofuels are not affected by the environment tax levied on fossil oil products as from 1999.

Production of biodiesel in France has been continuously decreasing since 2001, the year when France was the biggest European producer. In 2004 France produced 348,000 tonnes. Thus, the level of 387,500 tonnes set for obtaining tax exemption was not reached. Production of biodiesel in Italy reached 320,000 tonnes in 2004 which is an increase by 17.2 % as compared to 2003. More than 90 % of the production was intended for the fuel market, the rest being used in heating installations (mostly in the Vatican). Projections for 2005 show a decrease in the biodiesel quota by about 100,000 tonnes in favour of ethanol.

Among the other European states in 2004 Austria and Denmark stood out with a significant increase of production (respectively, 78.1 % and 70.7 %). Spain, Portugal, Great Britain and Finland also started biodiesel production.

Bioethanol

Bioethanol is the second largest biofuel market in the European Union with a production of 491,040 tonnes in 2004 versus 424,750 tonnes in 2003.

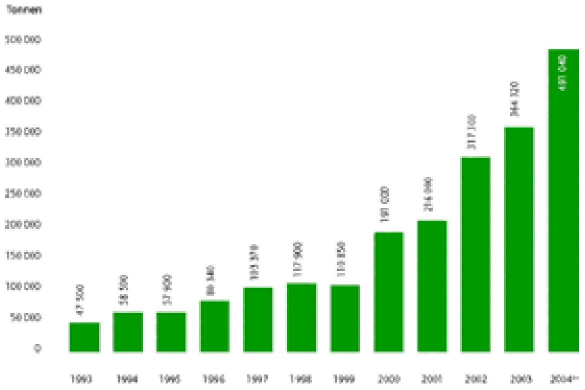

*Table 1: Production of biodiesel fuel in the EU for 2003 and 2004 in the EU; * error range +/- 10 % (Source: EurObserv'ER/EBB 2005)*

Spain is the leading biethanol producer within the EU with 194,000 tonnes in 2004 (and 160.000 tonnes in 2003).
In Spain, as in France, bioethanol is being converted in ETBE (ethyl-tertio-butyl-ether) and can replace the MTBE (methyl-tertio-butyl-ether) derived from petroleum as additive in motor fuels.

In 2004 France produced 102,000 tonnes of bioethanol which is by 24.4 % more as compared with previous year. But the French market has consumed only 80,887 tonnes.
In Sweden, however, consumption of bioethanol is much higher than the quantity produced within the country (in 2004: production 52,000 tonnes, consumption 206,000 tonnes). In Sweden bioethanol is not converted into ETBE but is added to petrol. Petrol containing up to 5 % ethanol has been offered on the market for long time now. Also, fuel under the name E 85 (85 % ethanol, 15 % petrol) for vehicles applying the Flexible-Fuel-Vehicles (FFV) technology is being used.

The biofuel market development is closely linked to a complete or partial tax examption for mineral oils in the individual countries. Consequent expenses for this type of encouragement lead to the introduction of production quotas in some countries in an attempt to limit the quantity of the biofuels favoured. In some cases, as a result of this, biofuels found themselves in a "closed" market, that is, a market where separate value creation sectors/chains are competing against each other. In any case, this restriction is only of political nature as the European legislation allows for total tax exemption for mineral oils, subject to preliminary approval, without any limits to production.

A comparison of current trends in development of biofuels in Europe with the 5.75 % target set by the EU in the White Paper clearly shows that biofuels would not achieve the desired market share. Despite it, the EU can still reach this target, if the biofuel market gets some eminence in countries such as Great Britain, Portugal, Belgium, Finland and others, in conjunction with abolishment of the production quotas.

The Kyoto Protocol and EU legislation on production of biofuels

Climate preservation has become an international issue on national and international level of policy. Undoubtedly, the most significant international agreement is the Kyoto Protocol of 1997 under which industrialized countries made a commitment to reduce their total emissions of essential greenhouse effect gases by at least 5 % below the 1990-year level in the period from 2008 to 2012. Germany ratified the Protocol together with the other member states in May 2002 and undertook, within an adjustment of burdens inside the EU, to contribute to the achievement of the EU common goal of an 8 % reduction through an own 21 % reduction by the first mandatory period (2008 – 2012).

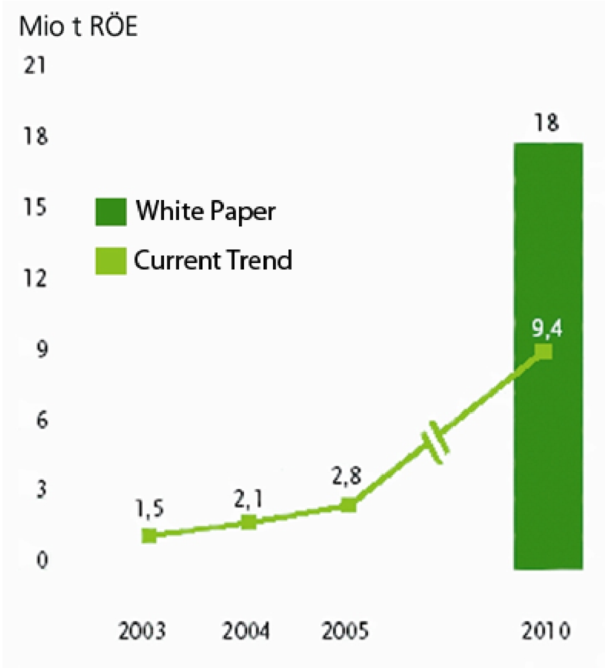

Fig. 5: Comparison between current trend and White Paper targets for biofuels in the EU (Source: EurObserv'ER, 2005)

In its 1997 White Paper 'Energy for the future: Renewable sources of energy' the European Commission put forward an indicative target - increasing the contribution of renewable energy sources from approximately 6 % in 1997 to 12 % of EU gross energy consumption by 2010 (EU "doubling target"). The absolute volume of regenerated energy should, however, rise two and a half times the previous level in order to achieve a relative double increase.

The highest rise is expected in the use of biomass. The increase in the share of renewable energy should be covered 80 % by biomass. This means a triple rise in the application of this sector and an absolute increase by more than three and a half times. In the meantime, this is being speeded up by encouraging the biofuel production.

A smaller absolute growth is expected from other renewable energy sources. Taking into consideration the small share in some cases, however, this can result in still higher relative rises as compared to biomass – for example, in the use of wind power and solar energy.

On a national level Germany also put forward a doubling target – the share of renewable energy should reach 4 % by 2010 (2 % in 2000) and continue its rise. This must contribute to the implementation of still one more target, and namely, carbon dioxide emissions to be reduced by 25 % until 2005 compared to 1990.

As transport sector accounts for one third of energy consumption in the EU, and this tendency being on the rise, a significant contribution towards the achievement of the above targets for reduction of greenhouse gases can be made in this field. In this connection, we have to mention the Green Paper 'Towards a European strategy for the security of energy supply' and the White Paper 'European transport policy for 2010: time to decide'. They set a European target of a 6 % share of biofuels by December 2010 and as high as a 20 % target by 2020.

European Directive on the promotion of the use of biofuels

In the meantime, most of the European goals for climate preservation were adopted as legally mandatory. Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport should be mentioned in the first place when the use of biofuels on European level is concerned. It stipulates for a gradual rise in the shares of minimal quantities of biofuels on the EU fuel market. The biogenic share which was above 2 % at the end of 2005 should become 5.75 % at the end of 2010.

The goals set by this Directive are reduction of greenhouse gas emissions, limitation of transport effect on environment, increase of security of energy supply, as well as encouragement of use of renewable energy sources. The minimal % share fixed in the Directive should contribute towards a substitution of biofuels for conventional fuels for Otto and Diesel engines and reduction of emissions harmful to health and environment.

At that, no difference is made between different forms of biofuels – they can be used as pure, blended or liquid fuel.

Member states were required to report to the European Commission before July 2004 the estimated biofuel shares they could reach by the end of 2005. In addition, setting of target levels lower than the above minimal quantities and their justification on the basis of objective criteria were to be reported. Members states are also required to submit to the European Commission every year by 1 July a report on measures taken for promotion of the use of biofuels and other renewable energy sources; national resources allocated for production of biomass for other energy applications outside the transport sector; total quantities of fuels purchased for the transport sector in the previous year . On its part, the European Commission would report to the European Parliament and European Council on the progress made in the individual European countries.

Some member states, however, have not yet identified the share of the minimal quantities. As late as March 2005 nine member states Belgium, Italy, Luxemburg, Poland, Slovenia, Estonia, Cyprus, France and Portugal have not reported to the European Commission the targets they were expected to reach by December 2005.

New CAP-Directives and prospects of growing crops for biofuels

The Common Agriculture Policy (CAP) has its origin in the 50s of the 20th century when production-oriented subsidies and fixed prices were guaranteed to the post-war agriculture. Changes in society and agricultural sector required from the CAP to take into account the new circumstances and at the beginning of the 90s a transition toward a market-oriented and environmental protection agricultural policy started.

The 2003-2004 CAP reform

In June 2003 the Agricultural Ministers of the EU passed yet another significant reform agreement for the Common Agricultural Policy (CAP) that would guarantee support for the agriculture, as well as long-term preservation of agricultural regions. After the CAP reform subsidies are granted subject to compliance with mandatory quality and environmental protection standards, safety of foods, health condition of animals and plants, as well as preservation of fauna, and at that direct subsidies are no longer linked to production. Farmers have the opportunity to act in accordance with the market demand and offer innovative agricultural products depending on market conditions. In addition, a mechanism to avoid exceeding of the EU-25 agricultural budget until 2013 was introduced to maintain budget discipline.

Regulatory framework for energy crops

The regulatory framework for energy crops contained in the CAP is of special interest to the biofuel sector. The 2003 CAP reform introduced an aid of EUR 45 per hectare to farmers producing energy crops. Growing of such energy crops that can be used in the production of biofuels for transport (as per the definition from Directive 2003/30/EO) and of heat and electric energy from biomass has been encouraged.

Farmers would decide on their own whether they want support for growing of energy crops through the currently effective regulations on Non-Food use of farmland or the new regulations. The new regulatory framework was adopted following the reduction of the carbon dioxide emissions.

As was said above, the aid is 45 EUR and is guaranteed for a maximum area of 1.5 million hectares all over the EU. This direct aid is subject to the CAP reform condition of growing energy crops under a contract concluded between the farmer and the processing industry, except if further processing does not take place in the producing farm.

Strategy for development of biofuel related processes

In order to achieve the targets set by the Directive on biofuels by 2010, all biofuel related sectors have to be included. At the present time, biodiesel and bioethanol are available in the market, while the other alternatives such as synthetic biofuels, plant oils and biogas for the transport sector should be still further developed. In any case, placing an emphasis on only one special biofuel should be avoided, and instead the whole range of various optional biofuels should be developed and mastered so that the best solution can be found for the individual applications.

Situation in Germany

The automotive industry and machine building, and also some German concerns specialized in mineral oils have been active in the research and development of future alternative concepts in the field of transport for many years. The strategies of several automobile manufacturers will be discusses in some details here.

Volkswagen concentrates on the development of synthetic biofuels (parallel studies on GTL-fuels and BTL-fuels are being conducted) which make blending with conventional diesel fuel possible.

Daimler Chrysler develops strategies for introduction and use of alternative fuels such as synthetic fuels and BTL-fuels, and relies on hydrogen in the long term. In addition, Daimler Chrysler works on hybrid concepts and automobiles with combustible elements (electrochemical generators).

BMW plans the long-term use of hydrogen as the only fuel, and in any case without combustible elements (electrochemical generators), but rather bivalent internal combustion engines.

The environment research plan of Germany contributes also to the development of common strategies for alternative fuels and motor technologies. Some EUR 1.1 million were invested in this field from 2000 to 2004, mostly on research for launching of innovative and environment-friendly motor concepts and alternative fuels in the market.

The current subsidies for projects in the field of biogenic fuels are some EUR 4 million within the Renewable Raw Products encouragement programme of the Federal Ministry of Nutrition, Agriculture and Consumer Protection.

The first projects for development of synthetic fuels (mostly BTL) have been already started with the aim of achieving regular flexibility and support for agriculture and forestry. Projects for production and application of biodiesel, as well as bioethanol from sugar beet and cereals are being encouraged only partially as these biofuels fall within the field of the engineering industry. Subsidies are granted for the use of plant oils in agriculture.

International situation

A great variety of projects for development, introduction and distribution of biogenic fuels have been started in Europe in recent years. Biodiesel and bioethanol have enjoyed a special support. Within the Sixth Framework Programme for Research and Technological Development, among other things, projects for production of BTL-fuels will be supported. At the same time, research work for the development of alternative engines such as, for example, combustible elements (electrochemical generators) and hybrid motor vehicles.

Outside Europe, especially in Northern America and Japan, more preference is given on research work in the sphere of motor mechanisms rather than fuels.

Biofuels and environmental impacts

Biomass products are known under the internationally accepted term “renewable raw materials”. Their advantages come from their organic origin. They are renewed on an annual basis or within some other relatively short periods. Renewable raw materials are used wholly or partially in the industry or as energy sources.

With the industrial revolution the need for raw materials of any nature and at the same opportunities for their processing increased at the end of the 19th century. A number of natural products were replaced with artificial and extraction of mineral resources increased with technical progress. In the 80s of the 20th century the danger of depleting fossil raw materials and agricultural overproduction lead to an awareness of the opportunities offered by the renewable raw materials of plant origin which can be grown on non-arable land without loss of support rights. In the meantime, ecological concerns are being raised much higher than agricultural and political arguments. Exhaustibility of fossil resources and the additional greenhouse effect related to their use, as well as the ever increasing quantities of wastes are crucial criteria for the development of new product lines from renewable raw materials. These new product lines have created environment-friendly and economically advanced production cycles that can be further manufactured also in the future.

Biofuels have a closed carbon dioxide cycle. It starts with photosynthesis during growth of the plant and ends with the release of the carbon dioxide during combustion. This cycle takes pace within a relatively short time - in oil crops it lasts one year, if ideal circumstances are present. In the build-up of their structure plants use dioxide from air, water and minerals and the sun supplies the necessary energy. In this way, the energy content of a plant is a chemical form of solar energy. Conversion of carbon dioxide and water in carbohydrates and oxygen is called photosynthesis. The chemical formula of photosynthesis is $6\ CO2 + 12\ H2O \dashrightarrow C6H12O6 + 6\ O2 + 6\ H2O$. At that, oxygen is formed only from the water molecules separated in the photosynthesis and not from the carbon dioxide, and is then released as a waste product. In the above example glucose (C6H12O6) is obtained as a primary product from which fat is subsequently formed during the growth process. The carbon dioxide is bonded inside this fat compound. Upon processing of essential crops fats are separated in the form of liquid oil and can be used, for example, as fuel for energy. In the burning process the carbon dioxide inside the plant oil is again released - plant oil and air oxygen will be burnt off and converted into carbon dioxide and water. The quantity of carbon dioxide released corresponds to the quantity received during photosynthesis. Therefore, the energy application of plant oils is not creating any additional greenhouse effect. This energy is defined as CO2-neutral.

To evaluate the ecological implications of the use of a certain product it will be necessary to study all possible environmental impacts throughout the whole life cycle of the fuel. Accordingly, all important production and application processes will have to be monitored, as well as disposal of waste products. And when it comes to fuel, growing, processing, distribution, use and eventually exhaust gases - all these play an important role. For example, in biodiesel production 40 % of energy consumption is required for conversion in esters, in production from rapeseed - about 30 %. Despite it, the climatic and energy balance is very positive for biofuels as shown in Fig. 6 for biodiesel and ethanol, even though the result is dependent on further use of the by-products (for example, rapeseed cake and glycerin).

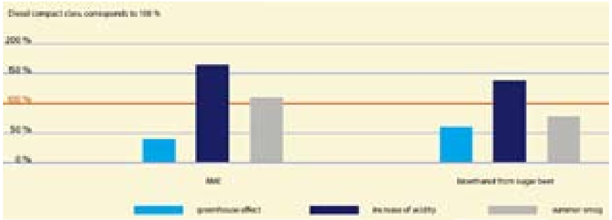

Fig. 6: Ecological advantages and weak points of biofuels compared to a diesel automobile car compact class

A study of the ecological balance of Volkswagen and Daimler Chrysler showed that with the use of BTL-fuel a 61-91 % reduction of the greenhouse gas is obtained though the life cycle as compared to conventional diesel fuel, and also that a reduction of carbon dioxide emissions by about 90 % is possible.

The following are some advantages from the use of biofuels:

- Any use of regenerative energy contributes to the delay of depletion of the precious fossil energy resources and at the same time harmful emissions will be avoided.
- Use of biofuels for energy does not cause any additional greenhouse effect. The carbon dioxide emitted during the production of energy and its absorption from the atmosphere by the growing plants creates a state of equilibrium both in terms of time and quantity.
- Environmental risks in transport and storage accidents are significantly less compared to fossil energy sources (for example, leakage in gas pipelines or damaged oil tankers).
- Use of biomass has a positive energy balance.

In general, biomass raw materials are of the same region:

- Thus, long and energy intensive transport routes are avoided.
- Regional chains for cost creation are set up.
- Dependency on energy imports is reduced.
- Use of biomass results in two types of circulation: alongside closing of the cycle of utilization of materials (CO2-neutral energy), a region can benefit from business flow circuits.
- Biomass applications have technical potential for development. Further research would be required to make them practical. New markets will be created.
- Agricultural structures will improve, work places will be kept or new jobs created.

Players involved

The players involved in the cost creation chain for biofuels cover the following wide range:

- Biofuel producers
- Agriculture
- Automotive industry
- Mineral oil industry
- Science
- Politics

It is important that these sectors form new strategic partnerships in order to create opportunities for productive cooperation for use of the available synergies and development and implementation of common strategies.

The biofuel producers are at the beginning of the cost creation chain. The supply market for arable land that will be used for production of biofuels will have a decisive role for this sector. The European agricultural reform provided the basis and the subsequent legislation on a national and European level will give a further impulse. Production of alternative energy sources contributes to the creation of new work places and brings profit to agriculture. In addition, local resources provide opportunities for cost creation in the region and bring about regional effects related to investment, revenues and employment. The extensive manufacturing system and innovation pressure create advantages also for small and medium-sized enterprises as state-of-the-art technologies will be in demand such as, for example, technologies for burning, mechanized systems for preparation of fuels and the like which will have to result in readiness to enter the market. The various advantages of biofuels are, of course, favourable also for the automotive industry which has been working in close cooperation for many years with scientists doing research in various fields and especially in development of new strategies and alternative concepts.

Growing of energy crops

1 Important energy crops

Under energy crops are meant plants produced specifically for energy applications. It is allowed to produce energy crops on farmland excluded for growing food/feed crops under the EU Set-Aside Programme. In general, the following concepts can be distinguished when growing energy crops:

	2004			2005		
Raw product	Arable land	Arable land not used	Area with energy crops	Arable land	Arable land not used	Area with energy crops
Starch	125.000	0	0	125.000	0	0
Sugar	7.000	0	0	7.000	0	0
Rapeseed oil	424.000	210.000	80.800	561.000	322.000	121.926
Sunflower oil		750	0		1.900	
Cereals	0	3.400	31.500		43.534	118.531
Linseed oil	3.000	100	0	0	0	
Fibre crops	2.000	0	0	1.500	0	
Herbs	4.000	400	0	4.000	182	
Others	0	350	0		2.811	2.320
Total	565.000	215.000	112.300	699.165	370.502	242.777

Table 2: Planting of renewables in Germany in hectares (Source: BLE, UFOP)

Cereals

The whole of the cereals above ground (grain and straw) is harvested annually and used for energy production. This method offers several significant advantages to the producer:

- known and well developed methods of growing
- no need to change the production process

- need of comparatively low additional investment.

Perennial grasses

The over ground biomass of perennial grasses withered after growth can be used as fuel. The advantage of grasses is that nutrients are transferred from leaves to roots at the end of the vegetation period. This makes the reduction of the use of fertilizers possible. One disadvantage for the farmer is that perennial crops would occupy farmland for a long period which does not allow flexible reaction to changes in the EU agricultural policy.

	Plant oil	Biodiesel	Biomethane	Bioethanol	DME	Hydrogen	BTL
Rapeseed	x	x	x		x	x	x
Sunflowers	x	x	x		x	x	x
Cereals			x	x	x	x	x
Straw				x	x	x	x
Maize			x	x	x	x	x
Potato			x	x	x	x	x
Sugar beet			x	x	x	x	x
Wood				x	x	x	x
Other biomass			x		x	x	x

Table 3: Raw materials for biofuels in Germany (Source: FNR)

Wood from short rotation plantations

In multiannual planting cycles the over ground growth of the biomass of fast growing tree species can be used. The advantage of this method is the relatively low consumption for growing of the crops. In addition, a short rotation plantation is planted only once and gives several yields. The long occupation of farmland is again a disadvantage.

A summary of the use of energy crops for production of fuels is given in Table 2 and further in greater detail in the enxt Chapter.

The following energy crops are of importance for the production of fuels in Germany:

Fig. 7: Rape (Source: LWK Hannover)

Rapeseed

Rapeseed is the most important energy crop in Germany and it belongs to the Brassicaceae family (= Cruciferae family). Rapeseed was cultivated as early as the 16th century. Now in Europe summer and winter rapeseed varieties are grown. The summer form of rapeseed is being grown as an essential crop in Northern Europe, while in mid Europe it is most often used as green feed, or as an interim crop. In Southern Europe where temperatures are not as low as required for creation of sprouts and flowers in winter rapeseed, summer rapeseed can be sown as early as in autumn. Winter and summer varieties are dependent on the genetically based need of low temperatures (vernalisation). There is a certain relation between need of cold and winter endurance. For example, winter varieties do not form long shoots in winter, but a rosette with a vegetation point deeply located and powerful root to enhance cold resistance.

Also, we can distinguish Eruca-rapeseed and 0- and 00-sorts. In 1974 the undesirable erucic acid in food products was eliminated through selection methods - the so called 0-sorts were created. The next success in selection came in the 80s when 0-rapeseed was replaced by 00-rapeseed. The content of glucosinulate in the latter was reduced to a great extent which significantly improved the nutritional value of rapeseed cake and meal. At the present, rapeseed of 00-quality is mostly produced, with the exception of Eruca-rapeseed specially grown for industrial applications (detergents, foam suppressants, etc.).

Fig. 8: Sunflower (Source: www.christian-vogt.de)

Sunflower (Helianthus annuus L.: family Compositae)

The Helianthus genus includes a great variety of plants, but of all 49 species only two are being used as cultivated crops (sunflower and Jerusalem artichoke (Helianthus tuberosus L.)). Because sunflower requires high temperature, in Germany it is being grown on large areas only in climatically favourable regions. As sunflower needs much heat, and especially during its main vegetation and ripening, there is a high risk when growing it in Lower Saxony.

Fig. 9: Sugarbeet

Sugar beet / Beta vulgaris

Sugar beet was cultivated from beetroot with the aim to obtain higher sugar content. At around 1800 researchers succeeded in increasing sugar content from the original 1.6 up to 16 %, while today it is 18–20 %. Sugar beet is one of the most important sources of raw material for production of sugar all over the world. The first sugar factory was launched in Silesia in 1801. Sugar beet is grown predominantly in the moderate climatic zone in Europe, but it is also produced in the USA, Canada and Asia.

Sugar beet is used also for production of bioethanol, but most of all as a raw material for industrial production of sugar.

Wheat / Triticum L.

Wheat is the most widely grown cereal crop in the world. It belongs to the cereal family (grasses) and descends from the emmer (Triticum dicoccum) and einkorn wheat (Triticum monococcum). The earliest archaeological evidence for wheat cultivation are from the time between 7800 und 5200 B.C. Thus, wheat is the second oldest cereal after barley. Wheat is grown on all continents and the biggest producers are China, India, USA and Russia. Of all areas with cereal crops in Germany the highest share is attributed to wheat.

Fig. 10: Wheat

Rye / Secale cereale

The production of rye has been suffering from the continuous decline of prices in recent years more than any other cereal crop. In the summer of 2004 market prices reached their lowest point - only EUR 6.50 per 100 kg.

The demand for rye, however, and especially in the energy branch, significantly increased. And so, this cereal crop which has no match on dry light sand soils is regaining its importance.

Presently, mainly the newly-built bioethanol processing plants in the new federal provinces fall within the range of consumers from the energy sector. These facilities have been specially designed for this lucrative raw material and their demand for rye is expected to reach about 1.5 million tons in the next two years. There is an extension plan for another 1 million tons by 2008. This would be almost 0.3 million of hectares or approximately 4-5 % of farmland with cereal crops. At the same time, the importance of the use of rye as a fermentation substrate in biogas processing facilities both as grain or whole plant is increasing. Rye is known for its ability to make a very good use of moisture in winter time and also to build up significant biomass even in lower temperatures in springtime.

Fig. 11: Maize

Maize / Zea Mays L.

As a result of intensive selection work maize is a high-yield, healthy and resistible crop even for the conditions of Northern Germany. Maize in Germany was grown on a total of 1.71 million hectares in 2004, of which 73 % for silage, 22 % for grain and 5 % for Corn-Cob-Mix (CCM). That maize is suitable for the types of soil in Northern Germany is confirmed by the fact that one-fifth from each of the above three major applications has been grown on Lower Saxonian land which applies also for the total area at 336.161 hectares or 19.7 % in 2004.

Because of its very good development of plant mass with high yield of dry matter, and its ability for adaptation to nutrients and water reserves (C4 plants), the silage maize is well in the range of vision of farmers and the other players in bioenergy industry specially for energy production at biogas or biofuel installations. Maize has a high potential for cultivation. Production machinery is also well known and with opportunities for further development.

2 Properties, efficiency, agricultural environment

The following is a presentation of some energy crops with their main characteristics.

Rapeseed

Botany

Rapeseed is an annual plant reaching a height from 1.20 to 2.00 m. It forms a central root as deep as 1.80 m. The plant has typically long hairs coming out of the root tips which are very helpful in the intake of nutrients and water from soil. The subsequent loosening and ventilation of soil during the intake process makes the rape a plant of much interest in terms of crop rotation. The rape develops a leaf rosette resting on the soil before winter time. The growth phase starts in spring when internodal spacing is increased and the stems grows initially without any branching. The process of branching will start only with the onset of flowering in the main stem. The broad leaves are of deep green colour, slightly haired and covering the stem only in the lower part of the plant. Despite that the flower structure of the rapeseed is completely intended for cross-pollination, self-pollination predominantly takes place. After a flowering of 3 to 5 weeks the fruits will develop. These are pods oriented upward, each containing 15-20 seeds of weight 4-6 g per thousand seeds. The seeds have brown-black reticulated surface and when ripe they will have 40-50 % oil content while the share of husk will be 12-16 %, and of crude protein one-fourth.

Location requirements

Rapeseed shall be planted in deep soils of high field efficiency and sufficient moisture. It does not endure moisture retention and soil compaction. Upon a uniform distribution of precipitation it can be grown also on clay and humus containing sand soils of soil number below 45. The rapeseed shows a well expressed need of vernalisation, yet it is not unlimitedly resistant to winter conditions – can endure temperatures down to –15 °C. But this will require reaching a 6-8 leaf phase in autumn development. In spring frost damages are possible in case of dry cold. With progress of development cold endurance will decrease.

Crop rotation

Rapeseed can be planted every four years at the maximum. It prefers peas, greensward or winter barley early ripening precrops contributing to soil looseness. As a rule, rapeseed is planted after winter barley, also often after winter wheat (the latter being reasonable after early harvest). At frequent crop rotation of cereals the positive impact of rapeseed as a leaf precrop shall be considered. When growing Eruca-rapeseed care should be taken about variety purity (separate crop rotation and storage will be required).

Varieties

The choice of a variety plays a decisive role in a successful growing of rapeseed. In general, hybrid varieties have been providing better yields in the average in recent years as compared to direct varieties. Higher expenses for hybrid seeds and comparatively lower oil content, however, should be noted. Therefore, hybrids are not necessarily placed ahead of the best direct varieties when efficiency is considered. Along with the oil content which should play as important role in the choice of a variety as the grain yield, the storage and disease endurance should be also taken into consideration by all means.

Yield

Rapeseed is the most important, productive and adapted to the agricultural conditions of Northern Germany essential crop. At average yields of 3.5 tonnes per hectare in winter rapeseed, the average yield of rapeseed oil is 1,200 litres per hectare. The range of yields in summer rapeseed is 1.5-2.5 tonnes per hectare. Out of all primordia 5-20 % will develop into flowers. About half of all flowers will form pods and only flowers blooming in the third week of flowering are yield-carriers. The number of pods and seeds is strongly dependent on competition in the plantation, the range being 150-800 pods per plant.

Quality requirements

Oleic acid (C-18:1-fatty acid) from rapeseed oil is an important raw material for the chemical industry. Also, the erucic acid which share reaches 50 % in erucic acid-rich varieties of rapeseed is of interest to the industry. Oil content of rapeseed is dependent on variety, location, ripening extent of crops and climatic conditions during vegetation (temperature sum). Along with rapeseed with its high oil content at approximately 40 %, rapeseed meal at approximately 35 % protein content is also a high quality by-product. Eruca-rapeseed production requires selection of special varieties containing at least 40 % erucic acid. The varieties of Erox (39.8 % erucic acid), Maplus (47.1 %) and Maruca (56.1 %) are permitted for planting in Germany. All varieties are either glucosinulate-free or contain very low levels.

Sunflower

Sunflower has cross-pollination. The flower head is composed of a multitude of single florets. Duration of blooming is 4-12 days depending on climate. The small single-seed fruits (a flower head can have 100 – 8, 000 seeds) are developed from the fertile tubular florets. The seed husk has four layers and is 10-60 % of the whole fruit. Fruits with a less share of husks are required for high oil yield. Oil content of seeds varies in the range 30 - 48 %. Composition is about 10 % saturated and about 90 % unsaturated fatty acids.

Botany

In addition to the central root, sunflower develops a highly ramified system of fine roots which make up 50-70 % of the total root mass. The plant can grow several meters of height, however, in cultivated varieties it is limited within 150-200 cm. Both stem and leaves are covered with tiny hairs and the stem in cultivated forms most often is not branching. But wild forms can branch. A sunflower plant normally has 20-30 hairy and broad, coarsely toothed, rough leaves. Young leaves exhibit heliotropism, that is, on sunny days they track the sun on its journey along the sky from east to west. At cloudless sky the leaves track the sun at an interval of 48 minutes.

Biology of the composite flower

The flower head is heliotropic until the onset of blooming. After this the flower head is oriented to the east which is favourable for pollination, fertilization and development of fruits (fungus contamination is minimized). The blooming flower head is of diameter 5-50 cm. It has yellow strap-shaped sterile corollas and fertile tubular florets. The strap-shaped corollas are arranged outside along the circumference of the head in one or two rows. The inside tubular florets numbering from 100 to 8,000 form spiral inclined rows. Pollination is done mostly by insects (bees and the like insects) and pollination through wind is rather scarce. If no cross-pollination takes place the stigma will continue to grow and curl up. Self-pollination will take place. The flower head fades from outer to inner side. During the whole period of blooming which lasts 8-10 days, from one to two spirals will fade daily.

Being a C3 plant, sunflower has a photosynthesis of especially high intensity. In this regard, it has similar qualities to the C4 plants. Because of its many large stomatas and relatively small CO2-resistance, the rate of photosynthesis is comparatively high at 40–50 mg CO2 per dm^2 per hour. Thus, it matches the performance of the maize which is a C4 plant. Another cause for the intensive photosynthesis is the heliotropic movement of the young leaves – they follow the sun on a cloudless sky and consequently absorb more light.

Fruit (achene)

The fruits of sunflower are achene, i.e., indehiscent single-seed fruits. The size of the fruits decreases from the periphery to the centre of the head. They reach a length of 7-25 mm and width of 4-13 mm. At their top the achenes are rounded and sharpened at the bottom. They consist of husk (pericarp) and seed. In addition to the size of fruits, the husk-seed ratio is also of importance for the oil yield. As a rule, less share of the husk means more seed yield. Generally, small seeds of higher specific gravity and small share of the husk have higher oil content. Oil content of seeds can be as high as 60 %, while the share of the husk is in the range 18 - 30 %. Sunflower seeds have a comparatively high content of proteins at 9 % - 24 %. Therefore, they play an important role both in human consumption and animal feed. Colouring of the husk varies from white and white stripes, gray and gray strips to black and violet-black.

Location requirements

Presently, growing of sunflower is of importance only in regions with comparatively dry and warm climate. Temperature sums of 1,500–1,700 °C should be possible to obtain at a reference base of 6 °C. The temperature sum is calculated by subtracting 6 °C from the average daily temperature and the separate values from the period of germination up to the harvest are added up. For the HO (high-oleic) varieties now available which ripen 10 days later in the average compared to the conventional varieties, the applicable rule is that they are suitable only for places where one another comparable crop such as the grain maize (FAO number at least 250) can ripen without any trouble. Along the southern regions, the regions with marked continental climate such as Thuringia, Saxony or Saxony-Anhalt are also suitable provided that the varieties do not show a trend to a later vegetation phase because of higher altitude (more than 200 m). Soils suitable for growing of sunflower are deep, well structured loess, loam and sandy-clayed soils.

Crop rotation

The importance of sunflower as a precrop is limited because of the fact that it heavily depletes water and nutrient resources. It extracts large quantities of water and much potassium from soil. Intervals of 4-5 years should be applied. Sunflower has no high requirements toward its precrop. Because of risks of diseases (Sclerotinia, Botrytis), it should not be planted immediately after rapeseed. Also, precrops contributing to a high additional supply of N should be avoided. In return, wheat and maize are especially suitable.

Varieties

The seed yield potential of modern varieties is in the range of 4.5 – 5 t/ha. Yield will rapidly drop below 2.5 t/ha at light soils and unfavourable water supply. Good varieties of sunflower can yield oil content of 50 % and higher. Along grain yield and oil content, early ripening, good endurance and limited disease susceptibility will play a decisive role in the choice of the desirable variety. Care shall be taken to distinguish between conventional varieties rich in linoleic acid and HO-varieties.

Harvesting

Timing: middle of September upon brown to black colouring of the bottom side of heads, dying of leaves and falling of flower petals. Harvesting moisture of seeds, if possible, shall be 14 % or less. Some special accessories and adjustment of the combine are needed to harvest the crop. These include wider adjustment of the counter-drum of the threshing machine, speed of drum at 500–700 rpm and low air blowing. At the end of the harvesting process the combine should be completely cleaned to avoid corrosion caused by the free fatty acids of the sunflower seeds.

Yield

1.5–2.5 t/ha (2.5–3.2 t/ha in regions of favourable climatic conditions, for example, France, Baden, Rheinland-Pfalz). In the region of Lower Saxony even varieties of early ripening will give a reliable yield only in hot summer time. The same applies to HO-varieties.

Quality criteria

Sunflower oil has a high content of linoleic acid which is a decisive factor for quality when used in the food industry. Because of the oil composition favourable for human physiology (unrivalled amino acid 44 - 70 %), the biggest portion of the sunflower yield is used for food-grade oil and margarine. Oil cake (40-50 % proteins) after refinement is used for animal feed. By virtue of its good drying ability sunflower oil finds application also in the production of paints and varnishes. In France it is used also for production of biodiesel fuel (plant oil-based methyl ester). The HO-varieties in which the share of the oleic acid in the total oil content is above 80 %, and even above 90 % in the new 90+ varieties, are preferable most of all for chemical applications.

HO-sunflower

Special attention is to be given to the HO-sunflower varieties which have an extremely high share of a certain fatty acid (the oleinic acid) in their composition. Present-day HO-varieties can be with oleinic acid content above 90 %. One such high level of a certain fatty acid is invaluable for the processing industry as the high costs for increasing of the concentration and for extraction of the required fatty acid (oleinc acid) can be minimized. At the present, the HO-varieties for which a permit has been granted, are Aurasol, Olsavil, Olstaril, Sunny and PR64H61.

Sugar beet

Botany

Sugar beet is a biennial plant which forms seeds only in its second year. During the vegetative development in its first growing season, it produces a rosette of leaves broad about 20 cm and long about 30 cm, while its root becomes larger and turns into a white tuber and can go as deep as 1.5 m. The reproductive phase comes in the second year and a 1.5 m stem with small flowers is formed. Sugar beet is grown predominantly in the temperate climatic zone and is produced most of all in Europe, alongside with the USA, Canada and Asia.

Location requirements

The sugar beet requires temperate temperatures, much light and much water. Also, soil shall be deep, rich in nutrients, of good water permeability as the water needs of sugar beet, especially in July and August, are high. Humus clayed and marl soils are most suitable, while light and poor dry sandy, tough clayed and shallow wet soils are not preferable.

Harvesting and yield

Sugar beet is planted from the middle of March until the beginning of May. Single-grain drills are used to plant the seeds at depth 2-3 cm in rows spaced at 30-50 cm. As a rule, 9-10 kg of seeds are required per hectare when a dribble type machine is used, and 15–20 kg with a drill seeder. A density of 7-11 plants per sq.m. is obtained. Harvesting is after the first growing season in the period between the middle of September and middle of November, when the root is at its maximum size and sugar content highest. Later harvesting has the advantage of increased sugar content. Normally, harvesting is done in three steps: fist, leaves and crown are chopped, and then the root is pulled out and finally picked up. Today all these processes are mechanized. Yield is in the range of 40 - 70 t/ha from which 10 tonnes of sugar can be produced. The leaves can be left on the field as fertilizer or used for animal feed.

Energy cereal crops (wheat, rye)

Cereal crops are used in many fields under various forms and their application for production of energy will be rising.

There are two main types of energy usage of cereal crops. First, the whole plant, that is grass and grains as wet substrate (silage) for biogas producing facilities or as dry baled biomass for direct combustion.

Second, only the grain is used. For biogas facilities grain is either stored dry or after preliminary crushing is ensilaged in wet condition.

There is also another type of energy usage - production of alcohol for fuel (ethanol, ETBE). It uses mainly rye and this application is now spreading wide.

In general, cereals can be used for direct combustion, but still there are some legal and technical obstacles especially for smaller installations below 100 kW.

Requirements for grain used for ethanol production

In first place, raw materials shall provide high yield of ethanol. Normally, this will be ensured by the high content of starch in the raw material. High starch content is, however, linked to low protein content, the latter being of no interest in the production of ethanol. In any case, this will be a source of conflict as the low content of crude protein in the waste cake used as animal feed reduces its value.

Also, along with good enzyme activity, the weight of thousand grains and hectolictric weight should not be neglected as parameters of importance.

Healthy condition of grain plays an important role in the production of ethanol. Mycotoxins, eventually present in Fusarium infection, will not decompose during the process and will pass in the by-product used as animal feed. DON (Deoxynivalenon) levels should be below 0.35 ppm and also the rye should not contain ergot (Claviceps purpurea).

Reasons for use of cereal crops for biethanol production

Wheat and triticale are of special interest to biethanol production as they have high starch content. The ethanol processing plant in Zeitz (Saxony) will work, for example, mainly with wheat as raw material. It will process around 700,000 tonnes annually.

In general, supply and price of wheat as raw material are decisive factors for processors. In theory, all cereal crops containing starch can be used for this production.

Rye is also an interesting source of starch for biethanol production as there are suitable conditions and relatively high and reliable yield in the regions of Eastern Germany. And rye gives better yield per average area compared with other cereals. In addition, production and delivery expenses are lower compared with other cereals. Despite that wheat and triticale have a higher starch content, their ethanol yield is not much higher than this of rye as a higher level of starch conversion is possible in rye during the process. Rye has partially a lower annual fluctuation in starch content as enlargement of the grain is less dependent on moisture availability. In years of high incidence the infection with fusarium in rye is markedly lower compared to other cereals and this results in better quality of animal feed (waste cake: 11-14 litres per litre of ethanol).

Starch content and ethanol yield

Starch content in grain determines alcohol yield and at thus the value of grain. According to the Union of Seeds, 1 % difference in the starch content was valued at EUR 0.17 per 0.1 tonne. At a yield of 70 tonnes per hectare this makes a difference in revenues of EUR 12 per hectare which at a producer price of EUR 9 per hectare is equal to 1.9 % difference in the yield. All measures that contribute to better development of the grains and at the same time reduce the content of crude protein will affect positively the content of starch. In addition, germination is to be prevented as in such event starch converts into sugar. Sugar can still be used for production of alcohol, however, decomposition leads to lower content of starch and consequently to reduction of value.

Health condition of the grain

Among the end products obtained in the production of ethanol is also the waste cake. Like waste beer wort, the dried cake containing protein is used as animal feed. This is one of the reasons to require raw products of good quality (for example, triticale, rye, wheat).

Grain health is of the highest priority as mycotoxins are not destroyed during fermentation and remain in the cake used for animal feed. As for the Fusarium fungi the levels of DON (Deoxynivalenon) and ZEA (Zearalenon) shall be kept as low as possible. Genetically, rye has good resistance, but still infection with ergot (Claviceps purpurea) shall be controlled with adequate measures to avoid reduction of value. DON levels shall be below 0.35 ppm.

Maize

Maize is with a very wide genetic variation all over the world. Intensive selection of many years has resulted in the creation of a comprehensive background used efficiently for selection of hybrids. The leading companies in the field hope to achieve significant rise in the dry matter yield from maize and subsequently higher energy yield per hectare very soon. In addition, maize falls into the group of the C-4 plants and has a special exchange of carbon which at higher temperatures and light intensity in the summer months increases the efficiency of photosynthesis. In this way, maize forms more dry matter content in addition to lower need of moisture as compared to other crops (C3 plants).

Soil cultivation and planting

Autumn or winter tilting is as much possible as the spring tilting. It is important to start cultivation only when the soil is ready for cultivation and machines will not cause compaction because of too much moisture. Spring tilting can provide an advantage as organic fertilizers can apply.

Mulching plants which are interim crops used only for fertilization are also very suitable and matching the traditional planting methods. Direct planting in uncultivated soil is also possible, if care is taken not to leave the seed uncovered with soil in the conical projection formed by the drill seeder. If direct planting is done by placing seeds in 10 cm wide by 10 cm deep furrow made by a cultivator, the yield will be similar to this when traditional soil cultivation is used.

Recommendations for density of plants in a plantation

Correct determination of the density of plants is considered as one of the most important condition in growing maize both for grain and silage. Taking into account soil and climatic specifics, conditions required for ripening and growth in the agricultural regions of Germany, between seven and eleven seeds are planted per sq.m. in both applications. In contrast to favourable locations with high precipitation levels, the number of plants on dry and sandy soils is to be reduced, especially in varieties with later ripening. In addition to number of plants, their arrangement also plays an important role. The conventional planting is in rows spaced at 75 cm, but also dense planting at 35 cm can be used. In the first experiments in this connection higher biomass yields were obtained on suitable soils. Other advantages of dense planting are, for example, better use of areas and protection against weeds because of fast shadowing. Disadvantages are higher expenses for cultivation, special machines for planting and harvesting, and no opportunity for mechanized control of weeds (hoeing, etc.).

In general, smaller spacing between rows gives at least the same results as in conventional planting (75 cm) in terms of yields, providing that own machinery is used for planting and harvesting.

Harvesting

Along with the choice of a plant variety, yield will be also much affected by the appropriate timing of the harvest. A too early harvesting will deprive us of possible higher yield, while late harvesting can result in reduction of biomass yield because of falling parts of crops. Experiments showed that for optimal biogas production harvesting shall take place at the beginning of the flour maturity. Dry matter content has to be 28 %, or still better 30-34 %. The yield of methane at one plant variety and same growing technique can be changed by up to 25 % only by shifting the harvest timing. At that, very often negative impacts from late harvesting are more serious than earlier harvesting.

Maize is to be harvested with a precisely adjusted combine at lengths as short as possible (2-4 mm).

Crop rotation

It is comparatively easy now to obtain yields of 15-20 tonnes biomass per hectare and methane 4,500 – 6,000 cu.m. per hectare using the impressive range of varieties available. Despite it, a well planned crop rotation shall be designed for the purpose of smooth energy production.

Winter interim crops which have its phase of growth in March/April, for example, are suitable for rotation of maize. Green rye or Italian rye (Lolium multiflorum Lam.) gives good yield when harvested at the beginning of May and maize planted as a second crop (moisture and nutrients provided) gives maximum yield of methane per hectare. The choice of the optimal time for mowing of the grass, maize varieties and methods in this crop rotation is still a subject of discussions. However, it is advisable to exercise caution in winter rapeseed and winter wild rapeseed as they cause the problem of high sulphur content in the biogas when used after their growth phase. The impact of the previous crop on the maize yield is quite various and the quantity of moisture plays an important role.

Varieties

For the time being there is still no special variety of an energy crop, but many selection researchers are working hard in this direction and it can be expected to have such maize very soon. Presently, there is a wide choice among the silage maize varieties. Varieties of good biomass yield are prevailing for energy purposes. The high content of fats, proteins and carbohydrates ensures more gas of better quality. High content of lignin due to maturing processes leading consequently to ageing is to be avoided. Therefore, maize varieties staying green longer time should be preferable („stay-green-types“). As maize varieties grown now can be harvested without the risk of occurrence of dripping juice at a dry matter content in the range of 28 - 30 %, it is possible to choose varieties of late maturity to make most efficient use of the vegetation period. Maize varieties of maturity range approximately +30 to +50 compared to local maturity ranges in silage maize varieties. In areas where, for example, S-250 varieties are normally grown, the maximum possible maturity range is S 290–S 300.

Selection

Selection work on energy maize varieties is now in progressive development. First of all, there are expectations for a considerable yield increase through a full utilization of light intensity by the plant in late summer and keeping the plant in vegetative phase as long as possible. At the present time, cold endurance of such Southern European maize varieties with late maturity is still a problem in Germany. The slow growth of the young plants of these varieties, negatively impacted by cold, is to be improved by combining with the cold endurance of selected German varieties. Also, experiments are being carried on with the aim of integrating genes of short day from exotic maize populations to stimulate intensive vegetative growth at the local long day conditions.

And also, maize varieties, especially those for ecological farming, are required to be suitable for growing without the use of preparations for plant protection (Low-Input) and have the potential for improvement of their resistance to noxious organisms.

The aim of the selection is to obtain yield of 20–30 tonnes of dry mass per hectare that will ensure the highest possible methane yield. A limiting factor in this respect is the moisture present in the soil. That's why, intensive work is going on for creation of varieties resistant to the draught-related stress which would be capable of developing sufficient biomass even at unfavourable precipitation levels, as was in 2003. According to first results, the Hungarian selection material showed good properties in the late range of maturing, while the German low-input material in the early range of maturing.

Biofuels as energy sources

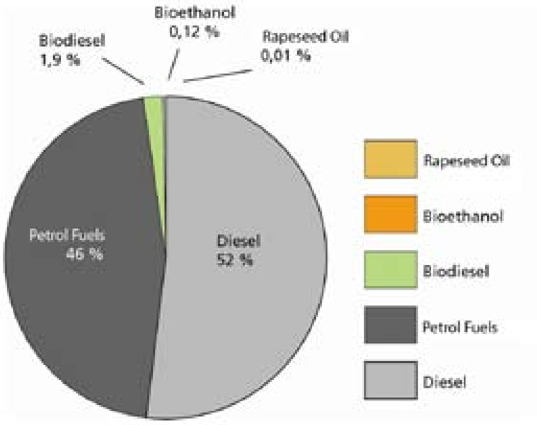

Fig. 12: Primary fuel consumption in Germany in 2004. (Source: FNR)

This chapter presents an overview of the available biofuels and the five types which offer the biggest potential according to the current level of development of science: plant oil, biodiesel, ethanol /ETBE, biomethane and BTL-fuels. A brief introduction to the use of hydrogen is also made.
The above biofuels have some quite different properties, technical requirements, economic potential, but their application in various fields is justifiable in view of the achievement of a steady flexibility.

In Table 4 are presented the most important properties of various fuels which will be discussed in detail further below.

	Density (15 °C) [kg/l]	Caloric value [MJ/kg]	Cinematic viscosity (20 °C) [mm²/s]	Cetane number	Point of solidification [°C]	Flash point [°C]	Iodine number [g/100 g]
Rapeseed oil	0,92	37,6	72,3	40	0 to -3	317	94 to 113
Sunflower oil	0,93	37,1	68,9	36	-16 to -18	316	118 to 144
Soya oil	0,93	37,1	63,5	39	-8 to -18	350	114 to 138
Linseed oil	0,93	37,0	51,0	52	-18 to -27	-	169 to 192
Olive oil	0,92	37,8	83,8	37	-5 to -9	-	76 to 90
Cottonseed oil	0,93	36,8	89,4	41	-6 to -14	320	90 to 117
Buckthorn oil	0,91	37,0	71,0	51	-	340	103
Cocoa oil	0,87	35,3	21,7 [1]	-	14 to 25	-	7 to 10
Palm oil	0,92	37,0	29,4 [1]	42	27 to 43	267	34 to 61
Palm stone oil	-	35,5	21,5 [1]	-	20 to 24	-	14 to 22

Table 4: Specifications of biofuels (Source: FNR)

In 2004 a total of 54.3 million tones of fuel were consumed in Germany, of which 52 % diesel and 46 % petrol, while the share of biogenic fuels rose at 2 % as shown in Fig. 12. The biggest share is attributed to biodiesel and rapeseed oil.

Energy and technical properties of biofuels

	Density [kg/l]	Caloric value [MJ/kg]	Caloric value [MJ/l]	Viscosity 20 °C [mm²/s]	Cetane number	Octane number (ROZ)	Flash Point [°C]	Fuel Equivalent [l]
Diesel	0,84	42,7	35,87	5,0	50	-	80	1
Rapeseed oil	0,92	37,6	34,59	74,0	40	-	317	0,96
Biodiesel	0,88	37,1	32,65	7,5	56	-	120	0,91
BTL	0,76	43,9	33,45	4,0	> 70	-	88	0,93
Petrol	0,76	42,7	32,45	0,6	-	92	< 21	1
Bioethanol	0,79	26,8	21,17	1,5	8	> 100	< 21	0,65
ETBE	0,74	36,4	26,93	1,5	-	102	< 22	0,83
Biomethanol	0,79	19,7	15,56	-	3	> 110	-	0,48
MTBE	0,74	35,0	25,90	0,7	-	102	-28	0,80
DME	0,67 [1]	28,4	19,03	-	60	-	-	0,59
Biomethane	0,72 [2]	50,0	36,00 [2]	-	-	130	-	1,4 [4]
Hydrogen	0,016	120,0	1,92	-	-	< 88	-	2,8

Table 5: Specifications of different plant oils (Source: FNR)

Plant oil

Plant oil has various applications. As a food product it is a main part of food either in the form of cooking oil or as a main ingredient in other food products, and it supplies important growth elements to the body used in the process of metabolism. Plant oil can be added to feed, while its by-products can be directly given to animals. Because of its exceptionally high energy content plant oil is suitable for use as a fuel for internal combustion engines, for combined production of electricity and heat, or directly for production of heat. On the other part, plant oil has very good properties as a lubricant. In areas not subjected to high loads, pure plant oil can be used for lubrication, while in higher loading additives will be needed. The positive ecological properties, for example, its minimal potential for harming of water, is a reason to use it as a lubricant that can be left in nature after application, for example, oil for power saws, grease for railway switches. The same applies for its use as a separator in construction concrete. And their application in frequent leakages in hydraulic systems also involves ecological implications. Not in last place, plant oils and fats can replace mineral raw materials in many fields of the chemical industry.

Oils and fats are contained in smaller or bigger quantities in all plants. They are present mainly in the plant seeds which are referred to as oil-bearing seeds. Oils and fats are not so often present in the fruit flesh (for example, in olives).

For the synthesis (formation) of oils and fats large quantities of energy are needed which, in first place, is supplied from the sun. Because of this, oil-bearing plants normally grow in the sunny zones of the earth. Special cultivation, however, makes growing of oil-bearing plants possible also in zones of temperate climate. Oils and fats can be in solid and liquid state depending on temperature. Oils are liquid at room temperature, fats are solid. All oils consist of hydrocarbon compounds. Plant oils and fats contain carbon (C), hydrogen (H) and oxygen (O) in different proportion. Because of different weight of these particles, weight range in all plant oils is comparatively equal. Carbon has the largest share at about 78 %, shares of hydrogen at about 12 % and oxygen at about 11 % are almost the same. Carbon, hydrogen and oxygen are contained in plants oils as triglycerides. These are compounds of the triglyceride containing three fatty acids. In addition, they have the so-called admixtures, mostly phospholipids, tocopherols and stearins.

Fig. 13: Structure of a triglyceride

"Fats and esters of the glycerin trivalent alcohol." This sentence as a whole would make any sense only when the individual concepts are known.

Alcohols (also: alcanoles) in chemical terms represent a group of organic compounds with one or more hydroxyl groups, that is, OH-groups. Methanol (CH_3OH) is the simplest alcohol. Then follows ethanol (C_2H_5OH) and propanol (C_3H_7OH) in the so-called homologous series.

The number of the hydroxyl groups determines the valence of the molecule. The above methanol, ethanol and propanol are of a single valence. The formula of glycerin is $C_3H_5(OH)_3$ and it is trivalent. Its structural formula is $CH_2OH–CHOH–CH_2OH$. The chemically correct name of glycerin is propane-1,2,3-triol.

The organic compounds of alcohol and acid are called esters. In the ester compound remains one oxygen atom from each OH-group of the alcohol and acid. The other oxygen atom and two hydrogen atoms form one water molecule (H_2O):

alcohol + acid = ester + water

When the alcohol is glycerin the ester compound formed is referred to as triglyceride. If the participating acids are fatty acids, this triglyceride is a solid fat. The structure of the triglyceride has the shape of the letter "E".

Fatty acids are unbranched monocarbonic acids consisting of one carboxyl group and a hydrocarbon chain, and belong to the group of the lipids.

The various properties of the individual fatty acids are due to two characteristics in which their hydrocarbon chains considerably differ: length of chain (number of C-atoms), and also number and location of the double bonds. In fatty acids double bonds are possible between two adjacent C-atoms, if they are linked only with one H-atom, that is, they are not saturated. Depending on the number of the present double bonds we can speak about saturated fatty acids (double bonds missing), simple unsaturated (one double bond) and polyunsaturated fatty acids (two and more double bonds) and so on.

Plant oils and fats consist of triglycerides of fatty acids with chain lengths from C 16 to C 18. Among these are the palmitic and stearine acids (C 16), and also the oleic, linoleic and linolenic acids (C 18). Plant fats with ten to fourteen carbon atoms, the so-called medium long fatty acids, are of considerably lower presence as compared to all other fats. These "lauric fats" (capric, lauric and myristic acids) are not found in Europe and are therefore supplied solely through import.

For designation of the chain length and number of double bonds after the letter C (carbon) are used two numbers separated by a colon. The first number stands for the number of the carbon atoms, the second for the number of the double bonds. The linoleic acid, for example, has 18 carbon atoms and two double bonds, and is denoted as C 18:2.

Several different fatty acids are always contained in the oil of each plant. However, among all these one certain fatty acid can be found significantly more often than the others. This dominant fatty acid is designated as a main fatty acid in the oil of the relevant plant. The proportional composition of oil from the different fatty acids is called fatty-acid model. The fatty-acid model is to a greater extent genetically predetermined, but also varies slightly depending on year and place of production.

The qualities of one exactly defined fatty acid are preferable for industrial purposes in most cases. The more dominant such main fatty acid is, the less the processing steps required for maximum utilization of its qualities will be. And this is the reason why the 00-varieties of rapeseed and high-oleic varieties of sunflower were selected.

And with the rapeseed there is also the fact that erucic acid as a main fatty acid in the conventional rapeseed is not suitable for human consumption. In contrast to it, the rapeseed of the 00-varieties has a fatty-acid model of food-grade which turns it into one of the most valuable plant oils. It is as much suitable also for fuel and lubrication oil.

With the selection of High-Oleic-varieties, sunflower oil in addition to being used as food finds also application for technical purposes. The high content of oleic acid makes it suitable for a lubricant at high temperatures.

Linseed oil as a basic substance in paints and varnishes has a quick drying ability because of the high content of polyunsaturated fatty acids.

Typical properties

The typical properties of certain plant oil are permanent to a greater extent.

Under **density** is meant the mass of a given volume of substance and the unit of measure for density is kg/m3. For example, at 15ºC the rapeseed oil has a density of about 920 kg/m3 and in this way it is about 8 % lighter than water.

Flashpoint denotes the lowest temperature at which a substance emits inflammable vapours. The flashpoint will go down with the increase of the content of free fatty acids in oil. A flashpoint is expressed in ºC (and also in ºK). The flashpoint of rapeseed oil is 230 ºC and this of diesel fuel is only 55 ºC.

Calorific value is the heat quantity of a fuel released at its full combustion during which the produced water vapour is in gaseous form in the exhaust gases. It is measured in kWh or MJ per weight or volume (for example, kWh/kg or MJ/l). In the past, this parameter was called lower heat value in contrast to the upper heat value; today we speak about calorific value and combustion heat.

Kinematic viscosity is a unit of flowability of a liquid measured in mm^2/s. The higher the viscosity is, the denser the substance is. Viscosity decreases with the rise of temperature. At 40 °C the kinematic viscosity of rapeseed oil is about 38 mm^2/s or ten times higher than this of diesel fuel.

Iodine number gives information about the unsaturated nature of the compounds contained in the fats. It shows how much iodine can be bound from 100 g oil (g iodine/100 g).

Content of sulphur is given in % by weight. In plant oils it is very low: 0.001–0.002 %.

Variable properties

Variable are such properties which are affected by the choice of plant variety, production and storage methods, and in this way play an important role in the production.

Under **total contamination** is meant the share of the solids (particles) not dissolved in the oil. It is measured as weight proportion in g particles /kg oil.

Neutralization number (also: acid number) gives information about the quantity of free fatty acids and it is affected by the extent of refinement and ageing. The acid number shows how many acid acting components can neutralize the oil. Comparison is made with potassium hydroxide and that is why mg KOH/g is used as a unit of measure. For rapeseed oil as fuel the maximum acceptable value is 2.0 mg KOH/g.

Stability of oxidation describes both the condition of ageing and preservation ability during storage of plant oils. When the oil is tested oxygen is added intensively and then a typically defined time for stability of oxidation is measured.

In plant oils phosphorus is present in the form of phospholipids. Levels below 15 mg/kg are required for use in internal combustion engines. Phosphorus content is dependent on the extent of refinement. In non-refined plant oils phosphorus content can be decreased by appropriate management of the technological process.

Ash content describes the presence of inorganic solids, for example, dust in the fuel. High ash content can cause damages to the injection system of engines. The maximum level for plant oil used as fuel is 0.01 % by weight.

Water content in plant oils is affected most of all by the moisture of the oil-bearing grain, but it can also rise at improper storage of the oil.

Plant oil as fuel

Natural plant oil has an energy value (caloric value) which is only a little lower than the fossil diesel fuel, but it is produced easier and at considerably less expenses. The plant oil is considerably different, however, from the diesel fuel in two parameters and because of this it cannot be burned in conventional engines without additional treatment:

- Plant oil has higher viscosity (low flowability).
- Plant oil has higher flash point and because of it is difficult to ignite.

As originally the diesel engine was not designed to work only with diesel fuel, the modern engines in mass production can be modified for a “come back” with less or more expenses. Then it will be possible to run them on plant oil as was demonstrated by Rudolf Diesel at the World Fair in Paris, France in 1900. The engine offered by him was powered by peanut oil. As an alternative to the engine modification, special engines suitable for the properties of the plant oil fuel were developed. They can burn pure plant oil of fixed quality. According to experts, the use of pure plant oil as a fuel in the future will be focused mainly on stationary applications (for example, thermal power plants) and agricultural and forestry machines.

Direct use of plant oils in diesel engines in mass production is hindered by some properties which make plant oils quite much different from mineral diesel fuel. To cope with these differences work is going on in two principally different directions:

- adaptation of the fuel to the engine, and
- adaptation of the engine to the fuel.

Along with the mixing method for VEBA and Tessol not yet ready to be launched in the market, presently the most widely applied approach for adaptation of the fuel is transesterification of the plant oil. In this process the glycerin is removed from the molecule of oil and fatty acids are again esterified with methanol. The new product is methyl ester of the plant oil (PME), or popularly known as biodiesel, and has properties very close to these of the diesel fuel. To use plant oil as fuel, modification of the motor vehicle will be required. In the meantime, such service is already being provided by specialized workshops for chamber engines, direction injection engines and pump-nozzle systems. There are systems with one or two tanks depending on the design of the modification.

Alternatively, engine specially designed for plant oils have been developed. They are available as chamber and direct injection engines and are especially suitable for stationary application.

Compared to mineral diesel fuel the two methods contribute to reduction of CO2 emissions. In addition, both methods are essentially free of sulphur and are less harmful to water. Plant oil supply infrastructure does not involve additional fuel consumption and transport routes are not longer and all this offers an advantage. Because of limited number of engines and related modification of motor vehicles initial investments are now higher than in the adaptation of the fuel, that is, the use of biodiesel.

Plant oil production

Rapeseeds are separated from straw at the time of combine harvesting. In most cases straw will remain in the field, but it will be better if it is used as a material, for example, for embankments, manure, animal feed or energy production (biogas, heat). Presently, however, it is not much feasible. The seeds of the plant are the raw material for the oil production. As economically it will be best to run continuous processing of the oil-bearing seeds, the length of their storage could be up to one year. High yield and good quality of oil will require, in addition to good separation of admixtures, adequate drying.

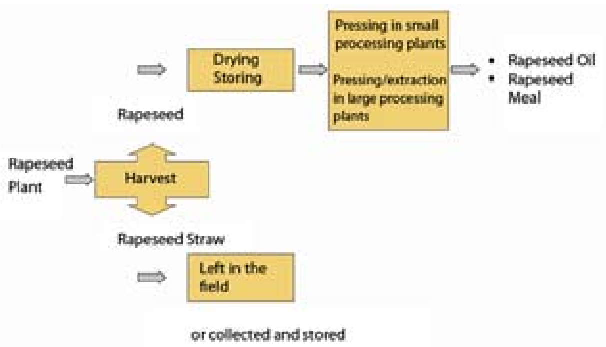

Fig. 14: Production of plant oil and by products

The real oil production includes the phases of preliminary preparation, pressing and refining. In an industrial processing each one of these phases consists of a number of separate steps, inclusive of chemical processes. Extraction yields a meal of very low oil content as a by-product.

Production at small decentralized installations is much simplified. As a result of the confinement within purely mechanical processes the number of the technological steps is reduced. The extent of pressing is lower compared to centralized processing of oil-carrying seeds, however the cake is richer in nutrients.

Industrial-scale processing of oil-bearing seeds

The largest part of oil-bearing seeds is processed centrally on a large-scale basis. Installations of such type are processing more than 500 tons of seeds per day. Now Germany is running 14 central oil processing plants.

In addition to cleaning and drying, industrial-scale installations employ what is called conditioning of oil-bearing seeds. In this process the moisture content and temperature of seeds are adjusted in accordance with the requirements of further processing. Eventually, seeds can be shelled and crushed.

In most cases, the real extraction of oil at large installations is a combination of preliminary pressing followed by extraction. After pressing the remaining oil is extracted with a solvent. The meal after extraction has very low oil content. The raw oil is refined. In Fig. 15 are shown the individual steps of the chemical refining: degumming, neutralization, bleaching and deodorization. The end product in industrial processing of oil-bearing seeds is refined plant oil.

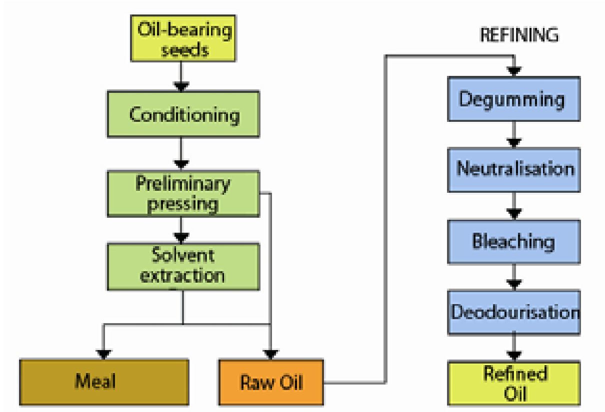

Fig. 15: Oil production at centralized processing plants

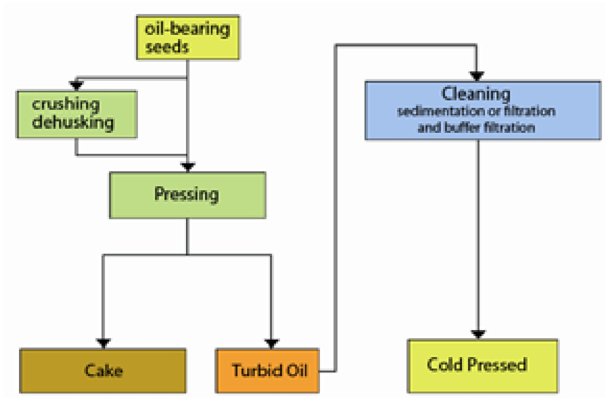

Fig. 16: Oil production at decentralized processing plants

Oil production at a small installation

Economic and ecological production of oil at decentralized processing plants requires an appropriately simple technological process. Also, energy consumption has to be minimized. Now, more than 200 small oil processing plants in Germany, mainly in the southern areas, are processing up to 25 tonnes of seeds per days following the above requirements.

Preparation of the seeds at a small plant is reduced to the most essential. Seeds which have been adequately cleaned and contain a proper moisture content after removal from store are processed without any other preliminary preparation.

Some oil-bearing varieties are shelled and milled, but in rapeseeds this is not necessary. The conditioning which is standard for industrial-scale plants is economically not reasonable here. Pressing at small plants is carried out exclusively by mechanized means and without any additional use of heat. Cold pressing produces turbid oil and cake relatively rich in oil. The only step for enrichment at small plants is cleaning of the turbid oil. For this purpose sedimentation and filtration are used. The end products from processing are cold pressed plant oil and cake rich in nutrients.

Centralized and decentralized oil seed processing plants differ fundamentally in terms of process expenses. Improved equipment used in industrial-scale oil production allows high capacity, but restricts considerably flexibility. Small processing plants can react in a fast and easy way to changing conditions by confining their operations within a small number of mechanized process steps. For example, essential oil crops not widely grown are processed mainly at small plants.

The extent of pressing at centralized plants is very high. Because of it, the cake produced after extraction as by-product is not so rich in oils as the cake from small plants. That is why, the cake from small plants has a wider potential for further use, for example, as animal feed.

The expensive design concept of centralized processing of oil-bearing seeds has high energy requirements: 1.7 GJ of energy in various forms is used to process one tonne of seeds, most of which for refining and also for steam production. As these operations are not present at decentralized plants, their energy consumption is considerably less. Also, these processing plants have no waste water from the production cycle, neither any use of solvents.

The two methods differ considerably also in terms of transportation expenses. While the centralized method requires covering of long routes, transportation expenses in decentralized processing of oil-bearing crops are very low.

Large oil processing plants require big quantities of raw materials and these are often supplied from neighbouring countries or even from around the world. Oil-bearing seeds are supplied by multi-tonnage transport where it is not rare to use intermediate storage sites. Because of these reasons, large oil processing plants need to have connections with central transport routes. In Germany almost all large oil processing plants are located next to big water courses such as navigable rivers or canals, and often have also a railway connection. Sales of refined plant oils are also made in large batches all over the world and these also need intermediate stations.

Small oil processing plants are located very close to suppliers and customers. In a perfect scenario, transport costs are confined up to the project site within the surrounding area. Quantities are small and can be transported with freight vehicles, more rarely by rail. In the southern areas of Germany distances between seeds producers, processing plant and market are maximum 50 km in many places.

The analysis of the economic aspects also defines a clear line between centralized and decentralized processing of oil crops. In most cases centralized oil processing plants are owned by big companies linked to large world concerns acting on international level. In contrast, decentralized processing of oil crops is carried either by family-owned small companies or cooperatives. At that, there is no intermediate trading and the processing plant is directly or indirectly related to the farm producer. Centralized oil processing plants are run independently of the farm producer, and outside traders are responsible both for the supply of raw materials and sale of the fished products.

Cost efficiency of industrial-scale processing of oil-bearing seeds can be readily assumed as granted in view of the large areas from which the raw material is supplied. Entering of international markets and good opportunities for storage ensure continuous availability of raw material and reliable sale of the finished products. Decentralized oil processing plants require the relevant regional structure for supply of raw material and sale of finished products. Only at such conditions the service of limited markets can be economically reasonable and opportunities created for enhancing the value added for agriculture and closed local work cycles.

Requirements on quality of oil-bearing seeds

Although the whole cycle of oil production starts with the choice of a plant variety and planting, it is the oil-bearing seeds that finally matter. In oil-bearing fruits oil is obtained from the fruit flesh (for example, olives).

In the period 1997 - 2002 average yields from winter rape in Germany were in the range of 2.97 – 3.69 tonnes of seeds per hectare. At the time of maximum maturity the seeds have the highest oil content. For example, rapeseeds of the plant variety 00 achieve 40-44 % oil content.

Several important conditions must be taken into consideration to minimize quality deterioration during storage and additional expenses from subsequent operations. One of the requirements is minimum admixtures and also a low share of broken seeds. In addition, moisture content and storage temperature are of importance; moisture content has a major impact on the storage life of oil-bearing seeds.

Oil processing plants are expecting to receive seeds of a certain minimum quality from farm producers. The acceptance conditions are updated annually, but there is a principle generally applicable. The real purchase price is reduced with a percentage representing the share of admixtures and broken seeds. In addition, to avoid price reduction the required maximum content of moisture has to be observed. Information on currently applicable conditions of acceptance can be obtained from the oil processing companies.

Storage of oil-bearing seeds

Different processes of decomposition and conversion take place during storage of oil-bearing seeds. They involve conversion of carbohydrate and most of all fats into carbon dioxide and water at which heat is released. Damaged husks of seeds are a special problem as microorganisms and fungi can enter and propagate. Heat and moisture are providing ideal conditions for their fast spreading. This will result in deterioration of quality, and possibly the total quantity could perish.

Moisture is a decisive factor for reliable storage. The optimal moisture of seeds is between seven and nine per cent. The risk of perishing and formation of mycotoxins, especially aflatoxins, above this level rises. Deactivation of aflatoxins is technically not applied and because of this the infected materials are generally not subjected to further processing.

Along with level of moisture during storage, the extent of contamination with admixtures also plays a decisive role. For example, dry matter loss in admixture-free rapeseeds of a moisture content 9 % after one year is only 0,4 %. This level can be further decreased at lower moisture. Different species of oil-bearing seeds have also different storage endurance. For example, linseeds are much more sensitive than rapeseeds because of their high content of polyunsaturated fatty acids and should be treated considerably more carefully during storage.

Storage of plant oils

Different molecular processes of decomposition and conversion occur in plant oils. As a result, oil quality can considerably deteriorate. In extreme cases changes can be so huge that oil could lose some properties required for certain applications. Whether and at what rate the processes of decomposition and conversion would harm the oil kept in store is dependent on various factors.

The previous history of storage plays a considerable role, i.e., quality of oil at the time of delivery to the store. It starts from the moment of harvesting, than drying and storing of the seeds and comes to quality of processing. High content of tocopheroles which is obtained through very good maturity and sparing processing is an advantage.

In the storehouse itself the quality of the plant oil can be affected by external conditions. And these are temperature, contact with water, oxygen and light, material of tank and other parts of contact. The most important changes that the oil can undergo during storage are decomposition of fats, self oxidation and polymerization.

Under **decomposition of fats** is meant removal of the fatty acids from the molecule of glycerin. This occurs when oil contains microorganisms and water molecules. The reaction of hydrolysis which takes place is a reversion of the condensation reaction during which a triglyceride is formed in the plant in the growth phase – fatty acids and glycerin separate again.

Self-oxidization is the chain reaction triggered by incoming air flow. This reaction impairs oil flavour and odour. Light and heat maintain this mechanism through supply of energy. At contact of oil with heavy metals such as iron or copper they act as catalysts, that is, the reaction needs less energy. Antioxidants (for example, tocopherols) can considerably prevent self-oxidization, if such substances are still present in the oil.

And finally, **polymerization** is a possible consequence of self-oxidization. As separate molecular parts bind in other formations, oil viscosity will increase and colour become darker.

In conclusion, the risk factors that could lead to deterioration in the quality of the stored oil will be again discussed in brief.

Contact with oxygen is the initial point of self-oxidization, heat and light supplying energy to this process. Ions of heavy metals such as iron and copper act as oxidization catalysts. This means that in the presence of one of these materials the reactivity of enthalpy is decreased and therefore the latter is positively impacted.

In contact with water hydrolytic separation of fats can take place. Enzymes or microorganisms contained in the oil cause separation of the chains of the fatty acids from the molecule of the glyceride. At that, one H-atom from the water molecule will bind with the glyceride, while the OH-group with the fatty acid. In fact, hydrolysis is the reverse process of the condensation reaction during which triglyceride has been formed.

When storing plant oils, opportunities for impacts by the above risk factors are to be minimized.

Ideally, temperature in the storage tanks should be in the range of 10 - 15 °C. Cooling or heating of the oil under the impact of the surrounding temperature is to be avoided.

Plant oils shall be stored, if possible, in dark places as light also transfers energy and in this way stimulates the processes of decomposition and conversion. Exposure to direct sunshine shall be strictly avoided. When transparent plastic tanks are used they have to be covered adequately. A better alternative is to use tanks that not transmit light.

Access of oxygen is to be minimized. For this purpose, in general it will be sufficient to fill the tank completely or use floating closing devices. Where requirements are higher, a nitrogen protective atmosphere is often used. It will be necessary to avoid filling by free falling from the top as this will cause foaming and entraining of oxygen. Filling is to take place at the bottom, if possible.

Contact with water can occur even only through the condensate. This has to be taken into consideration, especially when filling at low outside temperatures.

As during the undesirable processes of decomposition and conversion the ions of the heavy metals act as catalysts, it will be the ideal case, if tanks are made in high-grade stainless steel. Also, no brass or copper shall be also in the piping. Because of the more limited share of natural antioxidants in the refined oils, the latter are more susceptible to oxidization as compared to cold pressed oils.

Transportation of plant oils

Compared to other fuels, transportation of plant oils and also their storage are relatively trouble-free operations. Because of their high flash point and minimal risk for water pollution it is not necessary to adhere to strict safety requirements. Only care shall be taken to protect the oil quality against deterioration.

In general, at time of transportation plant oils are exposed to the same risks as during their storage. Heat, light, oxygen, water and ions of heavy metals are risk factors during transportation and can cause fast ageing.

First of all, “concealed” possibilities for contact with oxygen or water can be potentially harmful. Foaming, for example, is identical to intensive entering of oxygen and therefore should be avoided. Contact with water could eventually take place at time of filling, if the difference between the temperatures of the individual vessels results in the formation of condensate or the empty tank has not be well dried up after the cleaning.

Care shall be taken to keep the oil always in liquid state. Oil becomes turbid (segregation) as a result of cooling when the oil temperature drops to the point of solidification. Then oil will grow thick and finally solid and it will not be possible to pump it out. At normal transportation conditions rapeseed oil is liquid and there is no need of warming up. If during transportation temperature drops down to values which are in the range of temperature of solidification, oil has to be warmed up to maintain its pumping ability. The oil shall be warmed only several degrees daily as otherwise there is a risk of rancidity and other negative changes. Rapeseed oil produced by pressing can be cooled for a short time. After a longer storage oil solidifies into a white mass without loosing its quality.

Quality standard for rapeseed oil used as fuel

The preparation of a unified standard for application of rapeseed oil for fuel started in 1996. In the years that followed several research centres developed a Standard for Quality of Rapeseed Oil Used for Fuel (Qualitätsstandard für Rapsöl als Kraftstoff (RK-Qualitätsstandard) 05/2000). The leading partner in this project was the former Landesanstalt für Landtechnik (Regional Agency for Agricultural Machinery) located in Freisinger Stadtteil Weihenstephan. That's why, today we speak of a Weihenstephan Standard. As from the autumn of 2003 works have started on preparation of a national DIN standard.

Rapeseed oil for fuel is mostly produced in decentralized processing plants without refining. Within a project implemented in the period from December 2002 to May 2003, a total of 31 small processing plants of various capacities were studied, among which 16 have been suppliers for the 100-Tractors Demonstration Project. Only four of these processing plants were producing rapeseed oil meeting all requirements of the Weihenstephan Standard, another six failed to meet only one limit level. Five of the processing plants showed great deviations. Most of the deviations involved levels of total pollution and acid number.

Researchers draw the conclusion that rapeseed oil to the RK-Quality Standard 05/2000 can be produced in processing plants of any capacity, provided that appropriate care is taken to comply with all requirements. Also, according to this study the use of suitable filters could contribute to a reduction in total pollution. And also, an important precondition for production of high quality fuel is the use of high quality rapeseed plants.

Biodiesel

The plant oil methyl ester (PME) is formed by plant oil and methyl alcohol. In this molecular conversion the fatty acids are removed from the molecule of the glycerin and then bind with another alcohol.

Rapeseed oil and methanol are most often used and rapeseed methyl ester (RME) produced through the process of transesterification. The trivalent glycerin in the triglyceride of the plant oil is removed by three single valence methanol molecules. Today methanol is obtained most often from petroleum, while glycerin is a raw material more or less in demand in the chemical industry.

The rapeseed methyl ester is referred to as biodiesel all round Germany. The abbreviation FAME is also used in this connection (Fatty Acid Methyl Ester). Flowability and combustion properties of biodiesel to a certain degree are similar to those of the conventional fossil diesel fuel. As the fatty acids in biodiesel are no longer in a "triple package", the viscosity drops by about one tenth and is only a little above the viscosity of fossil biodiesel. In this way, the most important condition for application in modern injection systems and diesel engines has been fulfilled. To this are also added the high cetane number and 11 % oxygen content.

Biodiesel is classified as lightly harmful to water (WGK 1 = water harm class 1) and quickly biodegradable. Emissions of particulate matter from combustion are reduced by one third compared to conventional diesel fuel. Because of higher temperature of combustion, however, the levels of the nitrogen oxide (NOx) emissions of biodiesel are above the limits set forth in the EURO V-Norm which will come into effect as from 2008. Most probably, as early as the initial introduction of EURO IV-Norm starting from 2005, engines would have to be adjusted by installing a fuel sensor. This sensor will determine the proportion of the two types of fuel in the blend of conventional diesel and biodiesel fuel, and will optimally synchronize timing and stroke of fuel injection.

The requirements for composition and properties of biodiesel are set forth in DIN EN 14214. Thus, a continuous level of quality will be ensured to the consumer. Now, about 20 processing plants in Germany are producing more than 1 million tonnes biodiesel per year. Biodiesel can be purchased from more than 1,900 fuel stations.

According to an assessment by UFOP (Union zur Förderung von Öl-und Proteinpflanzen e. V. = Union for Promotion of Production of Oil and Protein Crops) biodiesel can replace up to 6 - 7 % of conventional diesel in Germany, and up to 10 % in the EU. These limited levels are the result of rapeseed requirements with regard to crop rotation. Against this background, in Germany a potential for growing of rapeseed crop on about 1 million hectares can be achieved.

Parameter			Diesel Fuel DIN EN 590		RME DIN EN 14214		Rapeseed Oil Weihenstephan	
			min	max	min	max	min	max
Density	(15 °C)	[kg/m³]	820	860	860	900	900	930
Kinematic viscosity	(40 °C)	[mm²/s]	2	4,5	3,5	5	38	
Flash Point		[°C]	55	-	> 101	-	220	-
Sulphur Content		[mg/kg]	-	350	-	20	-	10
Cetane Number		[-]	49	-	51	-	~39	
Calorific value		[MJ/kg]	42,7		37,9		35	-

Fig. 17: Parameters of different fuels

Comparison of 6 basic characteristics of fuels (see Fig. 17) shows that most of the biodiesel properties are very close to those of the conventional fossil diesel fuel. Plant oil, however, differs significantly from the other two fuels in many respects.

There are large differences between the conventional diesel and biodiesel fuel (RME) with regard to flash point and sulphur content. Diesel fuel has the lowest flash point and highest sulphur content.

Differences with respect to caloricity will be decreased if compared according to volume, and not by weight as done here. In such event, the caloric value of RME will be about 7 % below this of diesel fuel. Caloric value of rapeseed oil with respect to volume is only 2 % below this of diesel fuel and thus it remains very close to this level.

There are limit levels for diesel fuel (DIN EN 590) and biodiesel (DIN EN 14214) which are fixed in the European standards. Therefore, the consumer will receive a fuel of defined specifications and always of the same quality. In the sector of the plant oils a standard is available only for the rapeseed oil, however, it has no regulatory function. It represents an agreement between the owners of oil processing plants, engine manufacturers and researchers, and provides enhanced reliability for quality by compliance to accepted limit levels. The requirements of this Weihenstephan Standard most often are not fulfilled. Biodiesel is the first biofuel which falls within the range of the so-called standard fuels accepted for commercial use.

Fig. 18: a) Symbol DIN EN 14214 for biodiesel;
b) Symbol for management control of biodiesel at petrol stations (AGQM) (Source: FNR)

Description of ethanol fuel	
Raw materials	Cereal crops, sugar, wood
Annual yield per hectare	2.500 l/hectare
Fuel equivalent	1 litre ethanol replaces about 0.66 litre petrol
Market price	about EUR 0.50 /l
Reduction of CO_2*	30-70 %
Technical instructions	can be blended up to 5 % with fuel

* petrol equivalent

Table. 6: Description of ethanol fue

In Germany biodiesel is under the monitoring of the local agencies and public fuel stations are required to display the fuel standard by placing the DIN labels on the fuel pumps. German and Austrian biodiesel producers united in Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e. V. (AGQM) (Work Association for management of Biodiesel Fuel Quality) to ensure compliance with the standard. Out of all 1,900 public biodiesel fuel stations in Germany about 1,400 are owned by AGQM as indicated with labels on fuel pumps (see Fig. 18 b).

Transportation of biodiesel

Cooperation of all involved in the biodiesel sector will be required in order to keep the fuel quality. Transportation is by tank lorries. The transport vehicle is required to have an additional valid permit for its construction, a B-3 certificate and should have successfully passed a test according to § 29 StVZO.

Contamination and presence of water can cause problems and therefore it is advisable to conduct a thorough checking of transport vehicle and tank before loading.

As according to the requirements of DIN EN 14214 biodiesel shall have a flash point of at least 120 °C, it is not classified either as a dangerous substance or as a dangerous commodity for transportation by road/railway. It has to be noted that the addition of 1-2 % diesel fuel to the biodiesel can considerable reduce the flash point (below 100 °C). In such event, biodiesel has to be classified as a dangerous substance and commodity. Because of this reason, transport vehicles and tanks previously transporting products of flash point below 55 °C must not be used, if not cleaned before it. Also, transport vehicles used to transport any acids or bases, or glycerin and plant oils, have to be excluded.

In principle, the rule to be followed is never to mix or blend biodiesel with mineral fuels. Also, contact with water is not permitted.

Biodiesel has positive properties which fossil fuels can obtain only after use of various additives or by expensive processes. The biodiesel properties can be summed up in the following manner: biodiesel contains almost no sulphur, has very good lubricating ability, it is easily ignited by virtue of its higher cetane number and contains a high portion of oxygen (11 %) which ensures a better process of combustion. In addition, biodiesel can be used in winter at temperatures at around minus 12 °C and when additives are used its fitness is increased down to minus 20 °C.

Bioethanol

Along with biodiesel which is produced mainly from rapeseed, bioethanol from cereals (in Germany mostly from rye, wheat or triticale) will find application in the future. Maize, potatoes and sugar beet which also can be used for ethanol production for the time being have not be considered because of various production and technical reasons, such as, for example, highly limited storage endurance and high water content of sugar beet, and the same holds true of potatoes. In grain maize there exist factors of unreliability at late harvesting and extra expenses for drying. This explains the relative preference for cereal crops as raw material in ethanol production.

Raw Material	Yield (Fresh Mass) [t/ha]	Fuel Yield [l/ha]	Biomass required per litre of fuel [kg/l]
Grain Maize	9,2	3520	2,6
Wheat	7,2	2760	2,6
Rye	4,9	2030	2,4
Triticale	5,6	2230	2,5
Potato	44,0	3550	12,4
Sugar beet	61,7	6620	9,3

Table. 7: Raw material yields for bioethanol production (Source: FNR)

In France, Sweden and the USA biethanol has already established itself for years now, while in Germany the market has not yet become so successful. With the amendment to the mineral oil tax, conditions for development of the bioethanol market have considerably improved. Tax exemption for biogenic components in fuel blends will have a positive impact on the market for bioethanol use as early as the following years.

While plant oil and biodiesel can be used with diesel engines, bioethanol is suitable as a replacement of fuels for carburettor engines (petrol, super and super plus). According to current standards, mineral oil producers can add up to 5 % bioethanol in carburetor fuels and in Germany there is no large-scale production of motor vehicles that could be run on fuel blends containing higher per cent of bioethanol. This will require engine modification which to allow the use of up to 85 % ethanol blends (E 85). Motor vehicles fitted with such engines are termed Flexible Fuel Vehicles (FFV). Pure ethanol fuel can also be used, but only in special engines.

ETBE of up to 15 % by volume ocan be additionally added to the fuel for carburettor engines. ETBE is an ether produced from ethanol (47 %) and fossil isobutene (53 %) which can be used as a replacement of the fossil improving additive for the cetane number MTBE in fuels for carburettor (petrol) engines. Flexible fuel vehicles are now used mostly in Brazil, USA and Sweden. Bioethanol is produced by fermentation of plants containing sugars. Plants containing sugar, starch and cellulose can be used for production of ethanol. In Germany wheat, rye and sugar beet are used most often, while in the other European countries and the USA ethanol is produced mainly from maize, in Brazil from sugar cane. The current development of adequate enzyme methods will make production of ethanol from wood, energy crops and straw possible. This method, however, is still in the phase of development. Ethanol is produced by fermentation of the sugar contained in the plant through the assistance of yeast and enzymes. If the initial product is starch or cellulose, they will be first converted into sugar by the impact of the enzymes. The waste pulp is used for animal feed or as a substrate in biogas producing plants.

The properties of bioethanol contribute to improvement of the quality of fuel for carburettor engines as ethanol has higher cetane number than conventional types of petrol, as well as to the anti-detonation properties of fuel. Disadvantages of bioethanol, in first place, are its low energy content compared to fossil petrol (one litre ethanol replace 0.66 litre petrol) and rise in pressure of fuel vapours in the event of blending with fossil which has to be avoided, especially in summer.

The conventional production of bioethanol is an intensive energy process, but still the energy balance of the biofuel is positive. Compared to fossil fuels, carbon dioxide emissions per litre are 0.8-1.5 kg less. Also, because of its good biodegradation ethanol is not harmful to soil and water.

Pure ethanol (E 100) is used almost exclusively in Brazil, but even there it is now being progressively displaced by E 85. The use of E 100 has some disadvantages as compared to the blends (for example, E 85), such as poor ignition and ability to absorb environmental moisture.

Description of biomethane	
Raw materials	energy crops; liquid fertilizer and organic waste
Annual yield per hectare	4.700 m3/hectare*
Fuel equivalent	1 kg methane replaces about 1.4 litre petrol
Market price	no data
Reduction of CO_2*	no data
Technical instructions	Biomethane can be used in motor vehicles with natural gas fixtures, without any need of engine modification

* Basis: Maize yield 45 [t/ha]; Biogas yield 190 [m3/t]; Content of methane 55 %

Fig. 19: Description of biomethane (Source: FNR)

Raw material yield	Biogas production	Methane content	Methane production	Methane production
about 45 *	about 190 *	55	4.700	3.384

Fig. 20: Production of raw materials for biomethane production

Biomethane

Biogas is a gaseous energy carrier that can be used right now in vehicles running on natural gas. There are vehicles that can run only on gas and vehicles that can run both ways. Meantime, the latter are offered on large scale by different manufacturers. The biomethane produced from biogas can be used without the need of any technical modifications in the engines. In any case, the biogas has to have the properties of the natural gas. Its processing techniques are relatively new and have not yet been fully improved.

Biomethane is produced from biogas which in Germany is obtained mainly at agricultural installations by fermentation of liquid manure and maize silage.

The biogas contains methane (about 55 %), carbon dioxide, small quantities of hydrogen sulphide and other microgases. Methane is the only ingredient of the biogas which can be used as fuel and chemically looks very much like natural gas. Therefore, an important condition for use of biomethane is its separation from the other ingredients of the biogas which as already said is still not feasible.

Biomethane as a gaseous fuel is kept and transported with more difficulty as compared to liquid fuels and in addition, because of its lower energy density more space is required for storage. Natural gas transportation vehicles will be required to have additionally mounted tank suitable for keeping methane at 200 bar.

On the other part, methane has positive properties of combustion which reduce emissions of various harmful substances such as nitrogen oxides and reactive hydrocarbons up to 80 % compared to diesel and petrol fuels. The CO2-balance is also positive as the released carbon dioxide has to a greater extent been bound by the plants during the biogas formation cycle.

In Germany there are about 15,000 vehicles (0, 03 % of all motor vehicles) running on natural gas and they can switch to biomethane without additional technical modifications. However, there is still no adequate infrastructure of public fuel stations.

In general, two opportunities to set up the supply structure for this type of fuel are available. Biomethane can reach consumers through the existing natural gas network which has about 500 gas stations. However, there are still technical obstacles and a requirement to have a biomethane of properties similar to these of the natural gas. Alternatively, biomethane could be sold in gas stations built next to biogas installations.

Synthetic biofuels

Synthetic biofuels which are referred to as Biomass-to-Liquid (BTL) according the method used to produce them, are liquid fuels of properties similar to these of the diesel fuel. They are relatively new and their production is still not ready for the market. For the time being they are produced only at small research and pilot installations, but they show very good prospects for the future transport sector.

Various raw materials can be used for production of BTL-fuels, among which are waste products (straw, wood and other biomass products) and energy crops (fast growing plants, energy grasses).

Description of BTL fuels	
Raw materials	energy crops and wood
Annual yield per hectare	4,050 l/hectare *
Fuel equivalent	1 litre BTL fuel replaces about 0.93 litre petrol
Market price	no data
Reduction of **	> 90 % *
Technical instructions	Can be used in pure form or blended, without engine modification

* data based on calculations
** diesel equivalent

Fig. 21: Description of synthetic biofuels (Source: FNR)

According to estimates about 4,000 litres of BTL-fuels can be produced per hectare of agricultural land. This is approximately 20–25 % of the total fuel consumption (at energy crops grown on 4–6 million hectares), and Europe has a still higher potential (40 % of the total fuel consumption).

BTL-fuels are produced with a two-stage technology. First, under the influence of heat, pressure and oxygen the raw material put inside a special reactor will convert into synthesis gas, and after fuel components will be synthesized to be processed into BTL with properties similar to those of diesel or petrol fuel. Different methods are used for fuel synthesis among which are the Fischer-Tropsch synthesis process and methanol-synfuel synthesis.

Synthesis gases for production of various products (plastics, chemicals, fuels) have been produced from fossil energy sources for many years. The new thing about the BTL method is the possibility to use biomass which requires overcoming some technical obstacles. Heterogeneity of raw materials and the subsequent quality of the finished products is a problem. Logistics poses yet another problem as plant raw materials are available on decentralized basis.

Burning of BTL-fuels is very effective and complete due to the chemical properties of the hydrocarbons contained in them.

Synthetic biofuels provide the decisive advantage of adaptation to the current engine designs through a change and regulation of certain parameters of the synthesis process such as pressure, temperature and catalysts and some additional processing. In this way, BTL-fuels can be used right now without any modification to engines and their supply can be through the existing infrastructure. High production costs are a disadvantage at this stage.

In conclusion, BTL-fuels are offering a good prospective alternative that can be ready for the market not earlier than 2010. Of all biofuels, synthetic biofuels have the greatest potential and with their above properties, they give us bright hopes for the future.

Hydrogen

A great part of the society assumes hydrogen as the energy source of the future, most of all because of its good ecological properties, total lack of carbon dioxide emissions, infinite resources and wide availability. In general, application of hydrogen is of interest in three fields, and namely: use as a future energy in connection with expansion of use of the new energies; use as a possibly new fuel and in combustion chambers for production of electricity.

The origin of hydrogen, its excellent ecological properties and low production costs are decisive factors for its long-term use. Hydrogen is the most common chemical element on our planer, but because of his reactivity it can be found only bound to other elements (for example, water, hydrocarbons, biomass, natural gas, etc.). And as hydrogen can be isolated only through the use of energy, the length of its use and purity are dependent on the process of its production.

Presently, the production of hydrogen is: 80 % from mineral oil, 15 % from gases released by coal and about 5 % by electrolysis. When producing hydrogen from natural gas the specific emissions of liquefied gas are always more than the raw material as, from one part, energy is required for decomposition of hydrocarbons, and on the other part, carbon dioxide is always released in this process. From the point of view of energy and ecology, this makes production of hydrogen from natural gas senseless.

But hydrogen produced from natural gas is in any case cheaper than hydrogen from renewable materials. Hydrogen from natural gas is of worth 4 cents/kWh, while hydrogen from renewable materials is 12-13 cents/kWh.

As fuel hydrogen can be used in two types of engines: in carburettor engines and modified internal combustion engines.

Production of biofuels: transesterification, distillation, pressing

In this section production methods for the various biofuels are discussed. An important place is assigned to production of plant oils and biodiesel as for the time being these are the leading biofuels in Germany.

Plant oils

To get high yield and quality in plant oils it is essential that during the process of pressing the water content of seeds is about 7 % by weight. In addition, to have good quality plant oil, high purity will be required. Seeds shall be thoroughly cleaned from dirt and admixtures such as, for example, stones and metallic pieces, also for the purpose of protecting the machines. Magnetic separators, cleaning installation and screens are used in the cleaning process.

Drying and cleaning of seeds are done mainly before storing. When performed adequately and if seeds are stored at optimal conditions, no additional drying or cleaning will be needed before oil production.

In industrial-scale production of plant oil, seeds are shelled or dehulled, as, for example, is the case with sunflower. Then seeds are crushed at roll crushers. After that follows conditioning of crushed seeds, that is, water content and temperature are adjusted for optimal results. In small-scale production no preliminary dehulling and crushing of seeds takes place in view of avoiding additional energy expenses. In general, conditioning is often skipped because of high energy costs and need of subsequent refining, the latter being another separate process.

In fact, oil production at small-scale level employs a single process only. Oil-bearing seeds are continuously fed to the press where they are processed in a purely mechanical way. Pressing yields oil and cake.

In cold pressing, as well as in industrial-scale processing of oil-bearing seeds, screw presses are used. These machines have a rotary screw which feeds seeds to a pressurized cylinder. The press cylinder has radially arranged holes acting like a screen to let oil out and keep inside solids. There are two types of presses depending on construction of the holes: filter-screen and grid-cylinder screw presses. Solids reach the end of the cylinder and are discharged through an opening. This material is known as cake, and has the shape of small plates or pellets depending on the pressing method.

Cake produced in cold pressing has residual oil content in the range of 11 % - 18 %. This corresponds to oil yield (as well as pressing level) in the range of 75 - 85 %. Cake and oil are approximately in the proportion of 2 : 1, that is, one tonne of oil-bearing seeds will yield about 330 kg of oil which makes (when having high yield per unit area) about 1.2 tonnes of oil per hectare.

Plant oil produced by cold pressing still contains some solid material. The question is about seed portions which have passed through the holes of the press cylinder. These are turbidity-causing solids that will sediment and need to be removed by a clarification process later.

Irrespective of what will be the further use of plant oil, its purity is an important factor in the evaluation of quality. In general, there are two methods for mechanical separation of oil and solid material, and namely:

Sedimentation method: This method is based on the different thickness of oil and solids. Ordinary sedimentation machines use gravity. Solids will fall on the bottom of the tank and thus we speak of "sedimentation by gravity".

Filtration method: In this method the liquid to be clarified passes through a porous material that will retain the solids.

No matter what is the type of method applied, the oil is additionally clarified at another finer filter.

Industrial-scale production of plant oil

At large-scale plant oil production installations (of capacities 1,000 – 4,000 tonnes of seeds per day) seeds are first processed with hot steam and half of the oil is pressed out.

Then the oil remaining in cake is extracted by means of hexane, and the oil-hexane solution is distilled. The crude oil is subjected to clarification, bleaching and deodorization for refining to produce oil of extra quality. This method yields extraction of up to 99 % of the total oil contained in seeds at energy consumption 1.7 GJ per tonne of seeds.

Preliminary preparation

Preliminary preparation includes cleaning of seeds from admixtures by means of sieves, air separators, metal separator, etc. and washing. After washing seeds are dried up at linear or drum driers at temperature from 25 to 50°C to obtain residual humidity in the range of 6 - 8 %.

In certain cases seeds are dehulled before pressing. This applies, for example, to sunflower seeds which have shells containing high levels of wax that should not mix with oil. One such example is the oil processing plant of Teutoburger where rapeseed is also dehulled. This process involves a combination of rolls and crushers which are so adjusted that hulls would be crushed and finally separated through winnowing.

Advantages:

- Minimization of wear-out in pressing,
- Increase of work capacity and yield,
- Higher quality due to low temperatures in pressing chambers,
- Less fibre in cake,
- Possibility for additional use of husks.

Disadvantages:

- High investment,
- Need of storehouses for husks and transport,
- Loss of seeds at dehulling.

Seeds are crushed and compressed into flakes by pressing at counter-moving rolls in a flocculation machine. As a result, additional rupturing of cell structure of the broken seeds takes place to enhance oil extraction levels.

Pressing

Seed are conditioned with hot steam to obtain oil of lower viscosity. This process most often is done inside a heating tray.

In fact, preliminary pressing is the true production of oil. Seeds are pressed at a screw press where crude oil and oil cake are produced. The oil content of cake is in the range of 11 - 25 %. The solvent hexane is used to extract nearly all of the oil in the cake after pressing. Thus, solvent extraction leaves only about 0.5 % of oil in the by-product.

In practice, there are two ways of extraction: percolation method and immersion method. Both methods make use of counter-flow extraction, i.e., the extracting agent (hexane) and seeds travel in counter-flow. This means that there will be always contact of fresh solvent with already considerably oil-free seeds and of fresh seeds with solvent saturated with oil (known as miscella). The percolation method is also known as the continuous extraction process as it is based on the principle of continuous wetting of the material subjected to extraction.

The solvent flows along the material subjected to extraction and is absorbed by it. Continuous feeding of solvent provides fresh supply to replace the heavily oil saturated solvent.

The immersion method finds application in cases when it is difficult to extract oil from the cake and most often this is so when the plant material is highly rich in crude cellulose. In this method, all oil-containing material is submerged in the solvent. There is no forced circulation resulting in replacing the miscella with fresh solvent. Because of this reason, it will be necessary to apply mixing to obtain homogeneity.

Crude oil is separated from the solvent during distillation. For this purpose, use is made of the difference in the boiling temperatures of the two liquids. Hexane evaporates earlier and thus leaves the blend and is recovered and then cooled to liquefy for further use.

Preparation

In the process of toasting the portion of solvent left over after extraction and distillation is removed. A second distillation takes place in the toaster for further cleaning of the cake. Immediately after that the cake has to be cooled down and additionally dried up before storage. According to Verbandes Deutscher Ölmühlen (Society of German Oil Processing Plants) another positive effect of this process is reduction of glycosynolate contained in cake by more than two-thirds (through its degrading as a result of heat treatment).

Refining of crude oil

Crude oil contains substances such as contaminants, phospholipids, proteins, carbohydrates, oxidizing products, colourants, etc. which can have a negative impact, for example, on taste, smell and shelf life of oil. These substances are removed during the various stages of refining.

Crude oil produced from heat pressing contains up to 0.5 % (500 mg/l) phosphatides (lecithins). These gums are not stable thermally and would polymerize at temperatures above 200°C. Products from decomposition and degrading will impair taste and shell life of refined oil and can clog filters. And the aim of degumming will be reduction of phosphatide levels below 10 mg / l to make possible the next process of deodorization and respectively acidity reduction through distillation. Water degumming is used for phosphatides that can be hydrated. Hot oil of temperature between 60°C and 90°C is mixed with 1- 3 % water. After about 30 minutes the "swollen" phosphatides are removed by centrifugation. Phosphatides that cannot be hydrated are converted partially into a hydrated state by addition of acid (citric or phosphorous) or enzymes and will settle down. Then the oil sediment can be separated at a centrifuge.

Reduction of acidity / Neutralization

Neutralization with a 15 % caustic solution or distillation is used to remove the free fatty acids from oil. In the neutralization process water and soaps are produced and the latter are washed off with water and centrifuged, and the oil is dried up.

Alternatively, free fatty acids can be removed with hot steam of temperature from 180 to 260°°C and pressure from 3 to 5 mbar during the physical refining after the bleaching process. The free fatty acids are products of the decomposition of the lipids and can serve as an indication of the extent of decomposition, i.e., deterioration of oil. As a result of higher free fatty acid content the oil will grow rancid.

The aim of bleaching is separation of colourants (chlorophylls, carotenes, etc.), residual phosphatides, soaps and sulphur compounds through absorption in an active bleaching earth, as well as decomposition of hyperoxides eventually present. Degummed, neutralized and dried up oil is heated from 90 to 120°C and is then mixed with bleaching earth. After about 30 minutes bleaching earth is separated and removed by filtration. It is possible to use also active carbon at the same time.

Volatile aroma and taste substances (hydrocarbons, aldehydes, ketones, free fatty acids) are removed at temperatures up to 250°C with the use of water vapour that will entrain them. High temperatures and use of water vapour in the span of several hours can, on one part, result in decomposition (formation of trans-fatty acids), and on the other part, removal of desirable fatty substances from oil such as tocopherols (vitamin E).

In oils with high content of wax, for example sunflower oil, winterization will be necessary. This process involves slow cooling of oil down to temperatures below 10°C to encourage crystallization of wax whereupon it can be removed mechanically.

Small-scale production of plant oil

In general, decentralized oil processing plants have capacities in the range of 0.5 – 25 tonnes seeds per day and are operated most often by cooperatives. Compared to large-scale production the process here is much simpler and is confined to seed cleaning and drying, pressing and clarification of oil produced. The advantage is that valuable substances will be preserved, but on the other hand some undesirable compounds (for example, phospholipids), although in very limited amounts, will get into the oil. These processing plants yield 75 - 90 % oil and energy consumption is approximately 0.1 GJ per tonne of seeds.

High quality oil-bearing seeds, as well as good management of the process will be necessary to achieve high quality product on a regular basis. Decentralized oil processing plants can easily achieve a close cycle production and have advantages in terms of storage and transportation, and can be also more flexible to varying market demands (for example, sale of seed oil specialties). But it is of great importance to study well sale markets for finished products before proceeding with the construction of a processing facility. Germany operates now 200 of such oil processing plants.

Preliminary preparation

The preliminary preparation in decentralized oil processing plants is reduced down to:

- Cleaning
- Drying,
- And eventually dehulling of seeds.

These processes are similar to the processes used in centralized oil processing plants and because of it they will not be discussed again in this section. Grinding and processing up to production of flakes is of importance only in bigger seeds such as of sunflower and the aim is prevention of deposition at the feed funnel of the press. Most often these processes use 2 ordinary rolls to crush the seeds.

Pressing

A common practice is the use of screw presses available in different production capacities.

The screw mechanism has various shapes and helical lines depending on the kind of plant seeds processed. During their travel inside the machine the seeds are pressed by the screw against the walls. Oil separation takes place along the whole length of the pressing chamber through a screen bottom allowing the liquid to pass through. Different combinations of pressure and seed residence inside the press can be applied to affect residual oil content in the cake. Pressure can be changed by regulation of the discharge door of the cake, while residence time by the rotation speed of the screw. High pressure levels and long residence time will mean low efficiency of the press and high energy consumption.

Characteristics of cloudy oil

Clarification removes solids such as fine pulp and resins left after pressing.

In rapeseed oil we can have fragments from different parts of the seeds in the range of 0.5 – 6.0 % by weight (oil-free solids). Among other things, the content of solids in oil before clarification will be also dependent on extent of the wear-out of the press, throughput, moisture content of seeds and preliminary cleaning of seeds. Solids have to be removed completely, if possible, as most applications require minimum presence of solids (total contamination). Cloudy oil (crude oil) will contain about 11 to 13 % of substances that cause darkening and these levels have to be reduced. The desirable product quality is of decisive importance for the extent of clarification that will be applied. For example, when rapeseed oil is used for fuel, it shall have not more than 25 mg per kg total contamination, and particles shall be of size below 5 µm. Otherwise, particles can have an abrasive effect on engine injection nozzles.

Plant oil immediately after pressing is referred to as cloudy oil or crude oil. Cloudy oil is a mixture of substances in two phases – liquid and solid. Density and kinematic viscosity are important physical parameters in the separation of these two phases. For example, viscosity of rapeseed oil at 15°C is 920.00 kg / m ^{3}.

Sedimentation

Similar to filtration, sedimentation falls within the methods for separation of solid and liquid products. In the oil processing industry these methods are intended for clarification of crude oil. Sedimentation makes use of the differences in the density of liquid and solids – either by gravity or centrifugation. The two processes can be continuous or intermittent. The sedimentation behaviour is depending, among other things, on density difference, size and shape of particles, viscosity of liquid and interdependence between the particles.

Sedimentation by gravity requires relatively long residence time for oil inside the separation tank. This means provision of more storage area for crude oil. That's why, this method is used mainly in small-scale oil processing facilities (50 kg seeds per hour). A tank can be filled and discharged after a certain period to carry out sedimentation. In the Weihenstephan system a great number of sedimentation tanks are linked in series. The residence time of oil in this method is approximately 3-4 days.

The sedimentation strength of separators and decanters can be increased and thus residence time of oil in the tank cut down. This method has not been widely popular among small-scale oil processing plants until now.

Sedimentation is followed by a protective filtration at a filter with a certain size of the pores.

Filtration

In filtration, a suspension (in our case, cloudy crude oil) is forced through a filter. The particles suspended in the fluid, which will not pass through the filter apertures, are retained and build up into what is called a filter cake. The fine apertures necessary for filtration are provided by fabric filter cloths, by meshes and screens of plastics or metals. The fluid passing through the filter medium is called filtrate. Very often a thin preliminary coat filter aid such as cellulose or kieselguhr would be put on the cloth prior to the main filtration process to prevent fast clogging and also improve cake built up.

Small-scale oil processing plants use predominantly chamber or frame filter presses, but also vertical cartridge filters. Chamber and frame filter presses are made up of filter frames which are suspended face to face with a filter cloth fitted between them. The package of filter plates is positioned between one fixed and one mobile compressing plate, most often hydraulically. In frame filter presses the cake builds up in the recess between the frame and filter plate. In chamber filter presses the recess for the cake is formed by the double-side concave shape of the plates. The crude oil is pumped into the filter press through a center hole in the plates forming a channel. The filter plates are joined in a manner that allows to take away the filtrate. Removal of the filter cake can be either automated or manual.

The Friolex® method

The Friolex® method is fundamentally different from the universal methods for plant oil production. It uses no mechanical pressing for oil-bearing seeds. Instead, seeds are ground and then separated in oil and solids by purely mechanical means.

The well cleaned and dried up oilseeds are ground and mixed with water. A water-soluble food-grade agent is used as a process aid in a special decanter centrifuge to separate oil and solids. This is only possible if there is no emulsion between oil and the aqueous phase. As this is the case with most natural raw materials such as seeds, aqueous alcohol is added as an agent to break down this emulsion. It is not used as a solvent as in the solvent extraction process, but only as a purely physical tool for breaking down the emulsion. This makes possible the efficient separation between the oil phase and solids.

This method separates only the purely oil-soluble ingredients with the oil phase. This oil phase is of higher purity than the cloudy oil produced from pressing which means that degumming will not be needed. The oil is merely dried. The solids are also dried and the water and process aid removed.

The whole process is inert gas blanketed. The use of nitrogen provides the necessary protection for work carried out in the alcohol industry and also prevents any oxidation. The process avoids product damage and ensures production of valuable vitamins and non-saturated fatty acids.

The Friolex® process has been developed as a result of joint research by Westfalia Separator and Dr. Frische GmbH. The method is protected by patent in Europe as well as the USA and Canada. Depending on the particular raw material used, it can achieve average yields of 90 - 95%. Recipes and processes have so far been developed for more than 40 different oils.

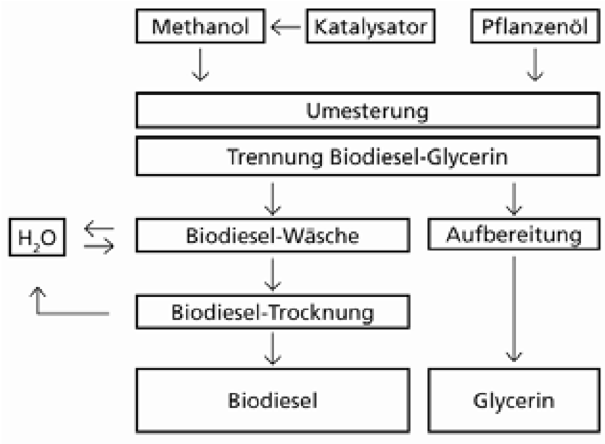

Fig. 22: A biodiesel production process

Biodiesel

Biodiesel is produced by transesterification of plant oil. For this chemical reaction plant oil is mixed with methanol at ratio 1:9 and various catalysts (mainly alkali metals, alkali hydroxides and alkali alcoholates) are added. Ester compounds of triglycerides in plant oil decompose at normal levels of pressure and temperatures from 50 to 80°C; fatty acids bind with methanole and thus biodiesel is produced. Another end product of this process is glycerine which has to be removed from the biodiesel. Glycerine is an alcohol that can find various applications in the pharmaceutical and food industries, as well in oleochemistry.

By rule, the process runs with an excess of methanol as the biodiesel production process is controlled by an equilibrium reaction which means that the reaction will stop when about two thirds of the primary substances have reacted. The excess methanol increases yields.

For the normal progress of the reaction it is very important to mix very well the primary substances in view of the limited solubility of methanol in oil.

As glycerine has different density, it will settle on the bottom of the reactor vessel at the end of the reaction and will have to be removed. Removal of glycerine has to be done quickly and completely to avoid any reverse reactions. At the same time, excess methanol can be separated.

The catalyst is a decisive factor for the speed of reactions, otherwise temperatures in the range of 300°C will be required and this will lead to thermal decomposition of triglyceride. After transesterification is over, the catalyst has to be deactivated or neutralized, for example, with acid. And before further use of biodiesel and glycerine so obtained, they have to undergo preliminary processing. This processing will be dependent on the type of catalyst used in the transesterification reaction.

For the normal running of the process it will be necessary to ensure that plant oil is of high quality. So, before transesterification ingredients such as phosphatides, sterols, tocopherols, wax compounds and free fatty acids have to be removed.

Bioethanol

In contrast to plant oil, bioethanol cannot be produced directly from plants. The raw materials for bioethanol production are obtained from plants after fermentation. During fermentation microorganisms will decompose carbohydrates and convert them into ethanol.

Alcoholic fermentation takes place according to the formula

C6H12O6 => 2 CO2 + 2 C2 H5OH.

Mature fermented mash is the primary product in ethanol production. Fermented mash is heated up to boiling point and the released ethanol vapour mixed with water vapour is recovered and upon cooling will condense into water ethanol solution. This solution contains residual products which are removed through rectification. Rectification contributes also to an increase of ethanol concentration up to 96 %, and a higher quality end-product can be produced by a multi-stage rectification process.

Production of ethanol includes the following phases: preparation of raw material, fermentation of converted sugar, distillation and rectification, water separation, processing of residual substances, storage and transport of products.

First, it will be necessary to decompose the raw materials containing starch and sugar. This process is different in different raw materials. When processing raw materials containing starch, the latter has to be converted through hydrolysis and addition of enzymes to low molecular sugar. When processing raw materials containing sugar, the latter is in the form of disaccharides, and it is decomposed into monosaccharides by yeasts and undergoes fermentation.

With the addition of yeasts during fermentation, monosaccharides are converted into ethanol and carbonic acid by means of the enzyme produced by the yeasts. Different production processes can be used (batch, cascade and continuous), but this subject will not be discussed here.

Removal of ethanol from the mature fermented mash is done at an alcohol distillation column. The ethanol-water mixture produced in the distillation column should have ethanol content in the range of 97.2 % and to reach this concentration a rectifier is used. A rectifier is a closed system where pressure and temperature can be adjusted.

As ethanol used as an additive in fuel for petrol engines should not contain water and in distillation this is possible only up to 96 %, another process have to be used to remove the residual 4 % of water. For this purpose, distillation with entraining agents can be used and also a membrane or molecular screen separation. The distillation mash is the waste product from the ethanol production and can be used as feed or manure.

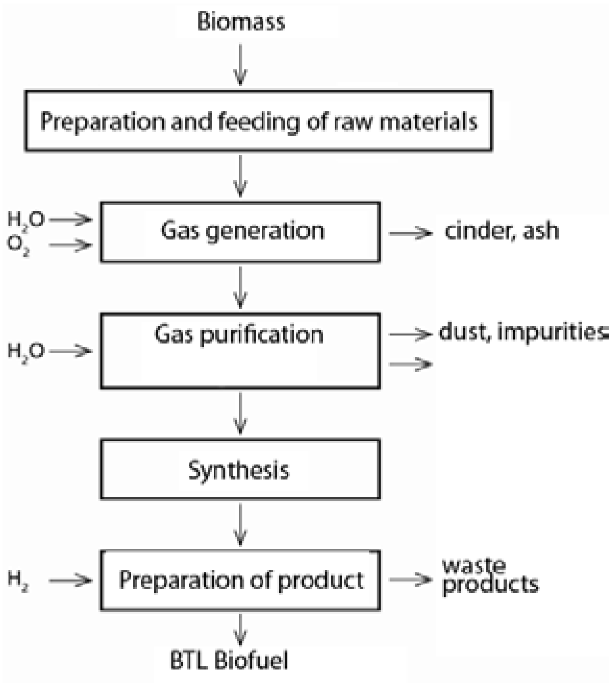

Fig. 23: Block diagram of production of synthetic biofuels (Source: FNR)

Synthetic biofuels

As discussed in Section III .1, BTL-fuels are produced in a two-stage process. Various raw materials can be used and the advantage is, as compared to conventional biofuels, that not only seeds are used, but the whole plant.

First, to produce a liquid fuel the raw material has to be converted into a synthetic gas. This is done thermochemically in a pressurized reactor, with heating and oxygen supply for gas generation.

The so produced synthetic gas consists of hydrogen (H2), carbon monoxide (CO) and carbon dioxide (CO2). The process described is still not well developed and requires further research to solve present technical problems.

The synthetic gas needs first purification so that components of the fuel can be synthesized. Sulphur and nitrogen compounds, and also others are removed to protect catalysts used in the synthesis.

The presence of carbon dioxide is necessary to obtain the proportion between hydrogen and carbon monoxide in the synthetic gas. So, the hydrogen level in the gas produced is increased through a water gas reaction. In this reaction water and carbon monoxide are converted into hydrogen and carbon dioxide, and the latter is removed.

In general, there are two main methods used for production of synthetic biofuels: Fischer-Tropsch synthesis and the methanol-synthetic fuel process. The first process is more popular and was first developed as early as in 1925. It is a metal catalyzed chemical reaction of carbon monoxide and hydrogen which runs under high pressure and temperatures between 200 and 350°C. In the second process the synthetic gas is converted in methanol and then into fuel.

Hydrogen

Production of hydrogen from biomass is by a gas generation process which has been known for more than 100 years as a method for obtaining of gas from coal, oil and gas. In this process the raw material is heated together with water up to 800°C to produce a synthetic gas composed of hydrogen (H2), carbon monoxide (CO) and carbon dioxide (CO2). This synthetic gas is further converted into hydrogen and carbon dioxide inside a reactor. The so produced gases as end products can be easily separated.

Use of biofuels: potential uses, technical solutions

Like all other fuels, the biofuels are also used for engine fuel and heat fuel. Biofuels can also replace boiler oil fuel. It is technically possible to run combined heat and power plants on biofuel such as biodiesel or pure plant oil. In combined heat and power plants the conversion of energy takes place in an internal combustion engine. Its waste heat is used for heating, while its mechanical energy generates electricity through a generator.

Biofuels for engines are used to generate mechanical energy. When this mechanical energy is used as motor force, for example, in automobile cars, lorries, barges and ships the point is about the transport sector. Examples of use of biofuels as engine fuel for stationary machinery are electricity generators, petroleum drills or pumps. When the point is about equipment that can be easily moved from one place to another, such as water pumps, lawn mowers or motor saws we call them portable or mobile equipment.

In all these application opportunities the pure plant oil has to be preferred in ecologically sensitive environment.

Plant oils

Plant oil has various applications and first of all it is an essential part of food. In the form of cooking oil or as food supplement oil supplies to the human body elements that are very important in the metabolic process. And it can be added to animal feed, while the waste products from oil production can be directly used in the animal diet.

Because of its exceptionally high content of energy, plant oil is suitable for engine and heat fuel: in internal combustion engines for generation of electric or heat energy, or in motor vehicles, or directly for generation of heat energy. On the other part, plant oil has good lubricating properties. Pure plant oil can be used for lubrication of areas which are not subjected to high loads; if loads are high, additives are used.

Positive ecological properties of plant oil, for example, its minimal potential for harming of water, is a reason to use it as a lubricant which can be left in the nature after application, for example, oil for saws, grease for railway switches. The same applies to its use as a separation layer in construction concrete. And their application in frequent leakages in hydraulic systems also involves ecological implications. Not in last place, plant oils and fats can replace mineral raw materials in many fields of the chemical industry.

As plant oils, like diesel fuel, are liquid hydrocarbons, the use of plant oils in diesel engines is possible in principle. Of course, plant oils have another chemical structure and show other properties in most of applications. For these reasons, adequate measures have to be taken to modify engines.

Irrespective of the oil production and fuel preparation methods, viscosity of plant oils is many times higher than the viscosity of diesel fuel. Only after reaching a relatively high temperature level, viscosity values of the two types of fuels will become closer. Thick plant oil causes problems as early as the stage of fuel supply and injection. Still more, in winter temperatures it may be even impossible to pump such thick oil. Plant oil has lower cetane number compared to diesel fuel, it is more difficult to ignite and this impairs start up performance of engines. Because of this, the fuel is not fully burned out in the stage of ignition and warming up of engines.

Another factor which makes combustion of plant oils in conventional engines difficult is oil deposits or coking. This can take place as plant oils which are not distilled contain substances which decompose at temperatures lower than the temperature of oil boiling. Areas which are most subjected to the peril of unburned fuel deposition are injection nozzles and walls of combustion chamber and one eventual outcome is piston ring sticking.

Modifications are required to enable the use of plant oil for diesel engines – first of all, a larger combustion chamber, higher turbulence of fuel mixture inside the chamber and/or combustion at higher temperatures.

Special engines for plant oil

Use of pure plant oil for engine fuel requires adaptation of engines to the properties of plant oil. At that, the point is about considerable modifications which will lead to better oil atomization during injection, higher combustion temperatures and larger combustion chamber.

Existing engines in full-scale production which use a pre-chamber and swirl chamber can be modified easier. Engines specially intended for plant oils generally have direct fuel injection.

Elsbett is a company which makes history in the development of engines for plant oils. This German company presented the first plant oil powered engine at the end of the 70s. A special feature of the Elsbett engine is the duothermic combustion system. The aim of the system is to safeguard against the loss of useful energy in the form of heat outside the combustion chamber. The fuel is injected tangentially and directed towards the inside of the combustion area, thus causing it to blend perfectly with the air. It does not reach the wall of the combustion chamber and, therefore, the formation of unwanted deposits is avoided. And also, this means relatively hotter center and colder outer area which leads to less engine cooling requirements. For some time such engines were offered for motor cars and lorries. In the meantime, Elsbett has specialized in engine conversion technologies. Today, engines specially designed to run on plant oil are used exclusively only for stationary applications. Some companies sell direct injection engines of 40 % efficiency, adapted to the specific properties of plant oils. Two of these special engines are shown on Fig. 24. The combustion chamber is accommodated inside the piston which is made in a material of a slightly less heat conductivity than the material of the cylinder. In this way higher temperatures can be reached during combustion.

One-tank systems

In contrast to two-tank systems, motor vehicles converted for one-tank driving can run only on plant oil. Older type engines with indirect injection of the oil fuel to the combustion chamber are more suitable for this purpose. For the application of this principle a modification for direct injection is also available. Whether a motor vehicle is suitable for one-tank system running on plant oil can be determined only on a case by case basis.

The steps necessary in a conversion differ depending of the vehicle make, model and engine condition. Very often certain proprietary details are not known, however, vehicle constructions are generally similar.

In motor vehicles with chamber type engines modifications are confined mainly to the fuel supply system and electronics. At least, materials non-suitable to be in contact with plant oil (that is, exposed to ageing due to the catalytic impact of materials) have to be replaced. To ensure proper supply of fuel to the engine some other modifications are also made, among which preheating of fuel (of course, not inside the fuel tank!), and sometimes it will be necessary to fit a fuel filter of higher capacity. And especially direct fuel injection engines require some further modifications of the injection and distribution system. Despite that some fuel injection pumps turned out to be not suitable for running on plant oil, atomization/injection of oil fuel can be done also through heated nozzles and nozzles with modified pressure and injection timing. Also, modifications of plugs are possible. Some companies modify parts of the engine such as cylinder head, valves, valve liners, piston, rings, etc.

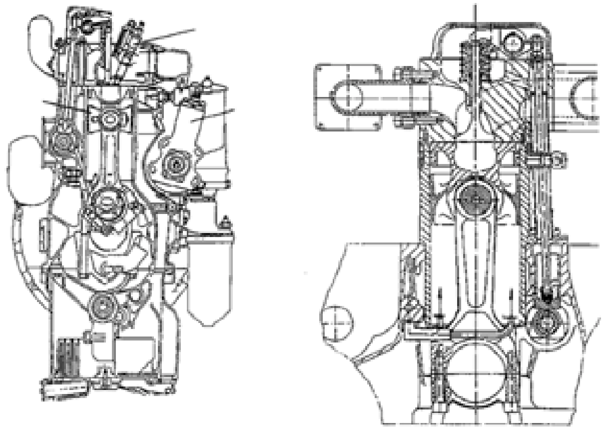

Fig. 24: Two examples of engines for plant oils

Two-tank systems

The problems experienced by conventional diesel motor vehicles with plant oil fuel due to higher viscosity and higher flash point of plant oil can be easily avoided by fitting a second fuel tank. In this way the motor vehicle can run on two types of fuel. Diesel fuel is used to start the engine. After starting and warming up of the engine the system switches over to running on plant oil. A few minutes before the end of the work cycle switchover is made back to diesel fuel for a short time to flush off remnants of plant oil in the system.

The main fuel tank is used for plant oil and a second tank is fitted for diesel fuel. The engine is started with diesel fuel from the secondary tank. Then follows a phase of warming up in which plant oil is preheated to reduce its thickness. When a certain working temperature is reached, the system will switch over to plant oil. Switchover is actuated by a solenoid valve which will start automatically through a temperature sensor or manually from the dashboard. The dashboard accommodates instruments which provide information on condition and type of the fuel currently in use. And at the end of the work cycle the system is switched over back to diesel fuel to flush off plant oil traces.

Modifications in the fuel supply system are identical to these in one-tank systems. Here, a “short-circuit” connection of the fuel line will be required which in combination with the solenoid valve will make preheating of plant oil possible.

Types of engines

The owner of a motor vehicle converted to run on plant oil will not experience much of a change. Differences in terms of power and consumption will be almost unnoticeable, and no big difference is also expected in wear and tear. In addition, it will be always possible to switch over back to diesel fuel supply, if there is no alternative.

German tax legislation provides an advantage in terms of type of fuel since biogenic fuels in contrast to mineral oils are exempted from taxation. But since the motor vehicle can also run on diesel fuel, no tax savings linked to the motor vehicle taxation are available.

Swirl chamber engines are converted in a much economic way to run on cold pressed plant oil. Both systems, with one and two fuel tanks, have proven their technical suitability for these engines.

More expenses are required to convert motor vehicles with direct injection diesel engines. Direct injection engines with in-line and rotary injection pumps can be converted and also operate with one-tank or two-tank systems.

The **pump-nozzle engines** are used solely with a two-tank fuel system. Conversion into a one-tank fuel system requires a much advanced technical level, but such engines are also available in the market.

The **common-rail type engines**, where a pump constantly supplies fuel at a very high pressure to the common rail - a tube with thick walls, are offered only by several small suppliers. Until now they have been available only with a two-tank fuel system. There is no sufficient experience from their use and their market viability has not been proved.

Stationary application

Rapeseed oil is a fuel of preference in ecologically sensitive regions. According to some experts, the use of plant oils has to concentrate both in energy for heating applications as this can contribute greatly to the reduction of carbon dioxide emissions, and also in ecologically sensitive regions where fast biological decomposition of plant oils is important. The more so as it is not possible to implement a wide-scale replacement of fossil diesel fuel for passenger and goods transport because this will require vast areas of arable land.

Examples for stationary application are electricity generators, heat boilers and combined heat and power plants. Agriculture and forestry, areas under the risk of flooding, protected natural parks and high mountains can be defined as ecologically sensitive. These places and regions are normally not connected to the public power grid and can be powered by combined heat and power plants.

On the other part, running of combined heat and power plants on rapeseed oil fuel is not always economically feasible. The too short total operation time and high expenses for maintenance are most often the consequence of poor quality of fuel. In some cases, the especially high levels of total pollution lead to economically unjustified operation and maintenance expenses. This is one more reason behind the efforts to promote rapeseed oil mainly for market segments where ecological implications have priority over economic concerns.

Biodiesel

Rapeseed methyl ester, or RME, or biodiesel – is the most widely used fuel of biogenic origin in Germany. It is produced from pure plant oil through transesterification and the hydrocarbons obtained are very similar to the fossil diesel fuel by their chemical-physical properties and molecular structure. Yet, unlimited application in diesel engines is not recommended without explicit approval from the engine manufacturer or seller.

Biodiesel dissolves deposits formed as a result of long use of diesel fuel and because of this it is recommended to change the fuel filter after several fillings of the tank and fuel system with biodiesel. Many motor vehicle manufacturers are recommending also changing of engine oil more often. Because of the sensitivity of varnish coated surfaces, contact with biodiesel is to be avoided, or after eventual contract surfaces should be cleaned. In addition, thinning of engine oil is possible, although in rare cases, and mainly in longer operation under low loading. Engine oil is to be changed on a regular basis.

Loss of power is less than what could be expected on the basis of lower energy content compared to diesel engine – it is in the range of 0 - 5 % due to some other properties of biodiesel.

Biodiesel, just like the ordinary diesel fuel, needs additives for winter applications. In Germany the use of additives is being done in accordance with an agreement between Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e. V. (Biodisel Quality Management Society) and its fuel stations (about 1,400) one month earlier than the time set forth in the standard. The cold endurance level of biodiesel is -20°C. Experiments showed 2.2 kg greenhouse effect gases per litre biodiesel less as compared with diesel fuel. Nevertheless, according to DIN EN 14214 biodiesel would not meet the expected European gas emission levels in modern engines.

On technical level it is possible to blend biodiesel with ordinary fossil diesel at any proportion. Still, there are some limits for the blend available in the market. German fuel stations can offer only fuels that meet DIN EN 590. Because of this, the addition of RME is limited to max. 5 %.

The legal situation of end consumers is different. They are allowed, with the exception of resale, to blend biodiesel and fossil diesel in their motor vehicle tanks without being liable to taxation. It should be taken into account, however, that such blend would meet neither the DIN EN 590 diesel standard, nor the DIN EN 14214 biodiesel standard. And so, the end consumer will bear the liability in connection with this blend. These provisions apply also for the supply of fossil diesel and biodiesel for the commercial market. To avoid taxation the two fuels would have to be transported in separate tanks.

Bioethanol

Bioethanol cannot be used directly as pure engine fuel for conventional engines. Bioethanol is suitable only for engines specially developed for running on pure alcohol.

Bioethanol can be blended with fossil diesel at a proportion of up to 30 % bioethanol after modification of the engine.

Blending with petrol fuels is not difficult and has even developed into an ordinary practice. In these types of engines bioethanol is used as a 20 -25 % blend without the need of any modifications. Higher alcohol content can result in segregation of the blend components that will cause disturbances. Bioethanol can be used as a fuel after chemical conversion into ethyl-tertio-butyl-ether (ETBE).

Use as pure fuel

The application of bioethanol as pure engine fuel is possible only with specially designed internal combustion engines which can run on ethanol blend of 70 – 100 % by volume with water. It should be noted that all parts in contact with ethanol have to be resistant to it, or otherwise corrosion can occur as many of the currently used sealing materials and parts are alcohol sensitive. This does not apply to materials such as steel, nylon, HD-polyethylene and polypropylene. Conversion of engines for running from petrol to ethanol is relatively easy. First of all, care shall be taken to avoid disturbances in performance in bad weather. For the cold start an additional tank is fitted for auxiliary start up fuel. The air sucked in after the start has to be preheated up to 90°C, which however will result in loss of engine power.

In conclusion, the conversion of a petrol powered engine into an engine running on ethanol is not recommended as it will require greater compression and other additional measures.

Use as a blended fuel

The addition of ethanol is possible both to petrol and diesel fuels, but in the second case it is not economically reasonable in view of current regulations.

As already mentioned, an ethanol blend of 20 - 25 % by volume with petrol will not cause problems and will not require additional modifications of the engine. But because of legal framework provisions the extent of blending is limited to only 5 %. Addition of ethanol to conventional fuels for carburettor engines can lead to changes as described in brief below.

The content of ethanol-water can endanger the phase stability and result in phase separation. This can be avoided by the addition of solvents.

The materials used in the manufacture of the engine have to be resistant to the fuel mixture which has a dissolving effect on elastomer materials and can cause corrosion in metals.

Solvents can cause corrosion to metals. A solution to these problems is the use of additives.

Use as ethyl-tertio-butyl-ether (ETBE)

Ethyl-tertio-butyl-ether is produced by chemical conversion of ethanol which is generally added to petrol fuels to improve octane number. Production takes place at petroleum-chemical installations and the process of transesterification is used with the addition of isobutylene obtained from fossil energy sources.

Synthetic biofuels

As BTL-fuels are produced in a synthetic way, their properties can be intentionally modified depending on the method of burning. Thus, these fuels would be able to response to future engineering developments and requirements.

Hydrogen

Hydrogen as a fuel finds application in two types of engines: combustion elements (electrochemical generators) with a connected electric motor and modified internal combustion engines.

Combustion elements (electrochemical generators): In the combustion elements (electrochemical generators) hydrogen can be converted into electric energy at high efficiency. Combustion elements can be stationary (as small cogeneration installations for heat and power) or used in the transport sector. In the transport they have the advantage of a high efficiency even under low loading (operation in urban environment). There are still problems with the storage due to technical and economic reasons. The automotive industry is very active in the field of research and good solutions will be available in the market very soon.

Internal combustion engines

In principle, hydrogen can be used as fuel both for petrol and diesel engines, but its use for the latter is not economically efficient. As with traditional petrol engines, preparation of the fuel mixture can be done in two ways. The outside preparation of the mixture has the advantage that the construction is simpler and injection pressure is lower, and the disadvantages are that the cylinder displacement is smaller and burning is irregular. In the inside preparation of the fuel mixture the injection pressure is high and more technical expenses are needed.

The whole range of biofuels has a potential of high prospects. Nevertheless, it is hardly likely that more than 20 % of the fossil fuels (petrol and diesel) would be replaced by biofuels or other alternative fuels in the following two decades of this century as they have started just now to find a place in the market. The German government, in conjunction with a group of experts, has developed four options which in view of the economic and ecological background represent a lasting alternative to conventional fuels. It has been found that optimization of the conventional engines and development of efficient and innovative driving mechanisms of low fuel consumption will contribute to the reduction of harmful emissions and guarantee energy supply security. Optionally, it is expected to enhance efficiency of petrol and diesel engines, further development of the production of synthetic biofuels, encouragement of the implementation of combined driving mechanisms and construction of efficient hydrogen storage facilities.

Economic implications

Profitability of agricultural products

The formation of a national market of biofuels is a decisive factor for agriculture in order to cut down the import of such fuels, create new revenue sources and new jobs.

Bioenergy can be considered as an active economic policy in the field of agriculture.

With the increase of yield per unit area and decrease of population, overproduction of foods is being experienced which results in a fall of market prices. Growing of plants and crops for production pf biofuels and biogas instead of food crops that are no longer profitable can offer an alternative use to the arable land.

An assessment of the German Ministry of Environment shows that the sector of new energies has created about 130,000 jobs, of which about 50,000 in the bioenergy branch.

In addition to the sale of the main finished products, for example, plant oil or biodiesel, an important role for the efficient economic operation of oil processing plants and transesterification installations will have the sale of the waste products such as rapeseed meal and glycerin. The two waste products are of proportional quantity compared to the main products. The demand for waste products is not related to the demand for rapeseed oil and biodiesel as the sphere of the meal and glycerin application is different.

One model of a regional economy with a closed production cycle, and also the regional markets, will be discussed below through the example of the plant oils.

The model of a regional circulation economy makes a closed production cycle in one not so large German region. Fig. 25 shows the application of plant oil starting from harvesting, production of plant oil and possible fields for its sale. The cycle closes with the growth of new plants. Until the harvest time these plants will spent the same quantity of carbon dioxide (CO_2) as will be released during the combustion of plant oils. Transportation at a short distance is a precondition to have a really closed circulation of CO_2. In a perfect case, the raw material for decentralized processing of oil-bearing seeds will be supplied from an area located at a maximum 50 km. Short transport routes not only reduceCO_2 emissions, but also contribute to covering of expenses. The regional circulation economy sets up new chains for creation of value: the money that previously went to distant areas or provinces now remain in the region and can be invested again. This circulation of funds ensures maintenance of jobs or creates new ones. Of course, the main requirement for development of a regional economy is the relevant market structure. Thus, for example, an oil processing plant needs to receive supplies of oilseeds on a regular basis and also to sell its oil and cake.

Prices of rapeseed and rapeseed oil in the national and international markets are determined by outside factors. This means that the dominant forces of pricing are not supply and demand of these products, but rather the availability of alternative products and their markets. Germany is one of the biggest producers of rapeseed and rapeseed products within the framework of the EU. Despite it, the decisive signals for prices are given by the international markets. Oil crops and their products are in a relatively close relation with the international markets and product interchangeability. The soya is the price leader among the oil crops, while soya and palm oils are in the front line of plant oils and fats.

In the regional market the agricultural producers, oil processors and traders have naturally different positions. Theoretically, the three market players determine the price of rapeseed oil and cake or meal in conjunction with the end consumers in compliance with the supply and demand principle.

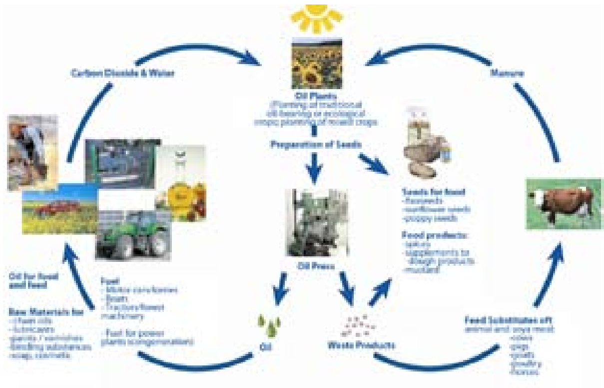

Fig. 25: Circulation diagram of a regional economy (Source: Bundesverband Pflanzenöle e. V.)

It seems that in recent times oil processors are in the best position as the price of the rapeseed oil has been determined to a great extent by the demand from the food industry and petroleum-chemistry industry (biodiesel!), and not so much by the supply of rapeseed. Cheap rapeseed and expensive rapeseed oil mean good profit for oil processors. Oilseed producers have always to watch closely the market to be able to respond to changing trends in due time. But even in this case forecasts of future direction are limited. Commodity exchange mechanisms such as future quotations and futures provide to oil crop producers an opportunity for a guaranteed price and are gaining increasingly higher importance in this market segment.

The cost and profit bill

Biofuels have to be competitive with conventional fuels both in ecological and technical terms, and also commercially. For the present, biofuels are still more expensive than

Table 8: Profit from sales of plant oil end products

Plant oil for fuel (mobile and stationary machines)	€ 0.45-06.6 /l
Plant oil for food	approx. € 2.50 /l
Plant oil for chemical and engineering applications	€ 0.38 - 0.56 /l
Oil for saw chains and separation agent	approx. € 1.00 /l
Oil press cake for feed	€ 11.20-17.90 /l
Heat application of oil press cake	€ 5.00-8.00 /l
Oil press cake for manure	€ 2.60-6.10 /l
Oil press cake as a co-ferment for biogas production	€ 0.00-6.00 /l

fossil fuels. Owing to public pressure for repealing of the ecological tax on fuels, today biofuels are in the market and are attractive compared to conventional fuels.

Most of the new production facilities for biofuels are still in the stage of development and not quite enough adapted for the market. Opinions about the economic effect are still too cautious, especially concerning to so-called second-generation biofuels.

There is an excellent experience of many years with plant oils and biodiesel. Below are discussed some considerations related to expenses and revenues from plant oils.

Revenues from sale of end products

Table 8 shows the profit from plant oil and plant oil products, inclusive of press cake. In addition to the investment for the construction of a modern oil processing facility and current expenses, the concepts of profit and value creation are of decisive importance in the assessment of the economic efficiency. Upon consideration of the possible revenues it can be seen that differences are quite high. This means that the profitability of decentralized oil seed processing is closely linked to the relevant price developments and consequently with the chances for a sale in the different markets. Development of the markets for rapeseed and its end products is again linked to the global markets for soya and soya meal.

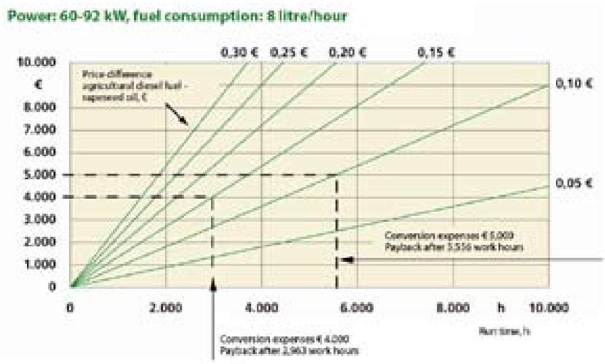

Fig. 26: Payback of a tractor conversion

Payback of a tractor conversion

In Fig. 26 is shown the relation between expenses for the conversion of a tractor and run time in hours for which a payback can be obtained. It is assumed that this will take place when the savings from the use of rapeseed oil replacing diesel fuel will cover the conversion expenses. Thus, the payback time will be dependent on the price difference between rapeseed oil and diesel fuel. For example, at a fuel consumption of 9 litres per hour the sum of € 4,000 will be saved after € 4,000/ € 0,15 /l / 9 l/ Rh = 2.963 Rh owing to the difference of € 0.15 in the prices of the fuels compared (Rh = Running hours). This calculation is much simplified as only the price difference is taken into account, and not any production and economic aspects such as loss of interest rate and the like. But the dependence on the relevant market trends becomes clearer - the more the price of rapeseed oil falls below the level of the agricultural diesel fuel, the more quickly the payback of the tractor conversion will be.

As from the beginning of 2005 with the amendment of the Regulation on diesel for agricultural purposes, the conversion to rapeseed oil is financially more attractive. This applies especially to enterprises with an annual consumption of diesel fuel above 10,000 litres which are not entitled to diesel taxation refunding. And as a result, the difference in the price rises dramatically with more than € 0.20 per litre which means that the payback period would be greatly shortened. Almost the same considerations apply also to biodiesel.

Enterprises with a high fuel consumption record should make an attempt to use biodiesel as a serious alternative to diesel for agricultural needs.

Comparison of expenses: excavator

Let us take an excavator with a volume of hydraulic oil 300 litres. A standard filter of worth € 100 is fitted; a filter for bio oil is € 100. Work expenses for replacement of the oil are € 100, expenses for a laboratory sample of oil are also € 100. Mineral oil is € 1.50 per litre, the most expensive bio oil is € 5 per litre. One filling with mineral oil will be 300 litres x € 1.50 = € 450. Plus € 100 for a new filter and work expenses we will have € 650, and also € 22.50 as leakage losses to make a total of € 672. 50.

If we assume that mineral oil has a service life of 1,000 Rh, then we will get the rate of € 0.67/Rh.

If we use bio oil, the oil cost for a filling will be 300 litres x € 1.5 = € 1,500. Plus € 150 for a fine filter and work expenses will make a total of € 1,750 for the first filling. A laboratory test of an oil sample is made after every 750 work hours and the filter is changed which will cost another € 250. Taking into account that bio oil can have a service life of 3,000 hours, this will have to be done three times (every 750 Rh, 1500 Rh and 2250 Rh) and will cost € 750. When € 225 are added as leakage losses, the total will be € 2,225. This makes € 2,225 / 3000 Rh = € 0.91 / Rh. At three times higher service life, the use of bio oil for the hydraulic system instead of mineral oil will increase expenses by around one third. This difference can be minimized by extending the service time.

Comparison of expenses: universal Unimog tractor with attachment

A universal tractor Unimog with attachment and volume of hydraulic oil 100 litres is taken as an example. A standard filter of worth € 70 is fitted; a fine filter for bio oil is worth € 100 and the cost of one laboratory test of oil is also € 100. The cost of mineral oil is € 1.50 / litre, the most expensive bio oil is € 5 / litre. One filling with standard mineral oil will cost 100 litre x € 1.50 / litre = € 150 for oil only. Plus € 70 for a new filter and work expenses will make € 320 and with € 15 as leakage losses the total will be € 335. If we assume that mineral oil has a service life of 1,000 Rh, then we will get the rate of € 0.34 / Rh.

If we use bio oil, the oil cost for a filling will be 100 litres x € 5 /litre = € 500 oil only. Plus € 100 for a new fine filter and another € 100 as work expenses the cost will be € 700 for the first filling. After about 750 hours of operation a laboratory test of an oil sample will be required and it will be about € 200. Taking into account that bio oil can have a service life of 3,000 hours, this will have to be done three times (every 750 Rh, 1500 Rh and 2250 Rh) and will cost a total of € 600. Leakage losses are assumed to be € 150 and so total expenses will be € 1,450.

This makes a rate of € 1,450 / 3000 Rh = € 0.48 / Rh.

At three times higher service life, the use of bio oil instead of mineral oil for the hydraulic system will increase expenses by around 40 %. This difference can be minimized by extending the service time.

Implemented projects

100 Tractor Demonstration Project

To demonstrate all success that has been achieved in the use of plant oils for engine fuel in agriculture the Ministry for Protection of Consumers, Food Industry and Agriculture (Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft) and the Agency for Renewable Raw Materials (Fachagentur Nachwachsende Rohstoffe) conducted a field experiment in Germany. Under the supervision of the University of Rostock the main performance characteristics and also the type and extent of the breakdowns in 110 tractors of seven makes and different models, converted for running on rapeseed oil, were recorded in the period September 2002 - September 2005. In June 2004 a preliminary conclusion was drawn. It showed that at an average of 1,360 running hours a practical readiness for a large-scale production cannot be established because of a lack of sufficient continuous experience. In 5 tractors the conversion method was assessed as being unsuccessful and these tractors were taken out of the project. Almost 30 % of the tractors displayed trouble-free operation. The number of tractors with small failures (< € 1,000) was a little above this percent and the same applies for the number of tractors with medium failures (> € 2,000). For breakdowns in 8 of the tractors more than € 15,000 were spent. Problems included loss of power, sticking of exhaust valves, defects in fuel injection pumps, problems with cold start up. Problems in engines with rotary injection pumps were greater as compared to these of the pump-supply line-nozzle type. Much of the breakdowns were the result of the still poor quality of fuel. More than half of the samples did not meet the RK standard, and only 10 of the tractors have always been run on high quality rapeseed oil. Random sample tests according to the COM 1 Exhaust Gases Standard failed. To meet the requirements of the COM 2 standard (the current standard now) and COM 3 standard, further research and development will be needed from the companies specialized in the conversion and from the engine manufacturers. The latter, however, show no readiness for cooperation.

The Deggendorf decentralized model of a production cycle

The company Maschinenring Buchhofen e. V. has a decentralized rapeseed oil processing plant in the administrative district of Deggendorf, Lower Bavaria, Germany. This plant was commissioned in the summer of 2001 with an initial throughput of 150 kg of rapeseeds per hour (which is almost 1,000 tonnes per year). It is possible to extend the capacity up to 5,000 tonnes per year.

The oil plant is operated as a limited partnership with about 70 shareholders (mostly farmers, but also some private persons) who with a minimum capital of € 3,000 each have contributed to bringing the funds needed. At the end of the fiscal year the profit is allocated between the shareholders. The shareholders can consider this money as an interest rate on the capital invested.

This limited partnership is managed by the plant operator and managing director of Maschinenring.

The Deggendorf oil processing plant was constructed just next to an existing corn drying facility. As a result, certain synergetic effects not of least importance were achieved, and more particularly, shared use of such equipment as weighing bridge, moisture content meter, grain drying and cleaning installations. In this building are stored both the oil press cake and plant oil produced.

The rapeseed fuel station is located on the same site. Its fuel tank has a volume of 5,000 litres and automated pump for self-service through magnetic cards. There are also several other rapeseed fuel stations built in the administrative district of Deggendorf. There is also a company specialized in the conversion of engines to biofuels which, among other things, has reconstructed the two tractors of Maschinenring to run on rapeseed oil and is participating in the 100 Tractors Programme.

CEP (Clean Energy Partnership)

In June 2002 the Clean Energy Partnership was set up in Germany within the framework of a European demonstration project and through the support of the German government. The participating companies are ARAL, BMV Group, Berliner Verkehrsbetriebe, DaimlerCrysler, Ford, GM/Opel, Hydro, Linde, Vattenfall Europe, and also TOTAL as from 2005. The aim of the project is the active support and encouragement for a stable flexibility through the development of solutions proving the universal application of hydrogen as fuel.

In November 2004 a demonstration project was started in Berlin. A hydrogen fuel station was constructed and integrated with a conventional petrol station located in Berliner Messedamm. Motor vehicle manufactures have provided 16 motor cars running on hydrogen. Part of the hydrogen fuel is produced on site; another part is delivered and stored.

The intention is to demonstrate the ability to unite a large number of developed technologies in a single system and to test both decentralized hydrogen production on site the fuel station (by electrolysis or reforming of liquefied gas) and delivery of fuel from another production site. And not in last place, to verify the reliable daily use of the motor vehicles.

As the origin of fuel plays an important role, this project conducts a test of the economic efficiency of hydrogen production from renewable energy sources under real working conditions.

At the same time, an attempt is being made to optimize administration processes and procedures for obtaining of construction permits for such energy infrastructure.

TOTAL is planning to commission a second hydrogen fuel station of the Clean Energy Partnership in Berlin in March 2006.

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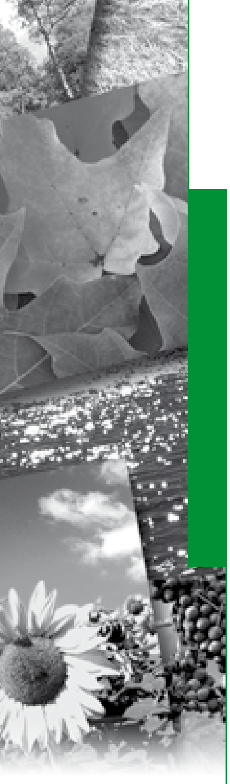


THERMAL SOLAR ENERGY

Introduction

The sun is not only a precondition for the existence of life on Earth but also a (quasi) inexhaustible energy source which will be still available for five billion years from now. Thermonuclear reactions occur at all times in the sun's core, in which hydrogen is transformed into helium. As a result energy is released and it reaches the Earth as light and heat. Within an hour the sun radiates to the Earth surface energy, its amount exceeding the energy consumption of the entire earth population for a year.

The solar radiation can be used both passively and actively. The consumption of heat and artificial light in buildings can be reduced through the passive use of solar energy. This can be achieved by orienting of the buildings to face south, by appropriate design of their structures and a suitable arrangement of their glazing areas. Windows and glazing areas protruding from the façade, light guiding elements, transparent heat insulations and heat accumulating materials are suitable structural elements for passive use of the solar energy.

Unlike it some technical aids and components are purposefully applied in the active use of the solar energy and in this regard, principally, there are two basic systems. The solar thermal installations produce heat by using collectors while the modules used in photovoltaic systems transform solar light directly into electricity. By means of such systems for active use of the solar radiation considerable amounts of energy are obtained in our latitudes.

The solar installations have a strong marketing potential and it is the appropriate roof surfaces that play a decisive role for the successful and widespread use of solar energy. In Germany alone the available roofs can accommodate several million of solar installations. In this way the roof functions not only as a protection from the atmospheric impacts, but also serves for the production of ecologically clean energy without any noxious emissions. In order to respond to the esthetic requirements the solar elements should not appear as imposed foreign elements disturbing the roof landscape which often happens in an additional installing. Their integration into the roof should be preferred and thus to replace the conventional roof cover.

The different manufacturers of solar collectors offer skylights and innovative collectors along with photovoltaic modules of appropriate grid dimensions and appearance. This gives the opportunity for well suited arrangements of the skylights and solar elements in different patterns meeting the increased architectural requirements.

Solar installations are used in order to save the energy produced in the conventional way and to reduce the CO2 emissions released during the burning process of fossil energy carriers. As a rule the energy produced from the sun is offered for use in the conventional energy systems, i.e. there should be a connection point of the solar installation to a common type supply network. In principal the solar installations for active solar energy use can be divided into two systems of different energy types.

The thermal solar installations (collector installations) produce thermal energy and supply it to systems for household water heating, for warming or heating of water in swimming pools, and in special cases, to cooling systems.

The photovoltaic installations (PV- installations) produce electricity and supply it to the available AC network (PV-installations connected to the mains), or supply it directly to a particular consumer or a battery (autonomous PV-installations)

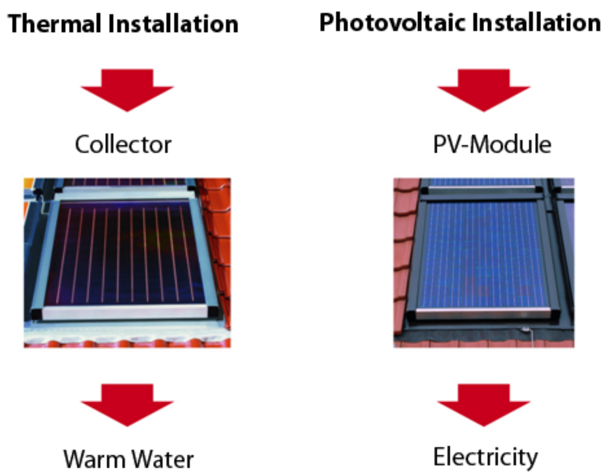


Fig. 1: Options available for active solar energy use

Solar Thermal Industry in Europe

After almost 10 years in which the solar market in Germany used to mark a growth of 10%, in 2002 there was a dramatic decrease by 23.7% in comparison with the previous year (see fig. 2). In 2003 a lot was done for achieving the aim set by the European Union (EU) - 100 million sq m collector surface installed by the end of 2010. Then 1.450.000 sq m of solar collectors were installed in Europe - an increase of 22% compared to 2002. This tendency persisted in 2004 plus additional 10%. The success is attributed mostly to the 10 new member states. Detailed information is given in Table 1.

Germany is the greatest market of thermal solar installations in Europe with an area of 750.000 sq m of collectors installed in 2003 (+39% compared to 2002) and 780.000 sq m in 2004 which represents an increase by 4% compared to the previous year. This tendency is explained by the more limited subsidization after January (110 €/sq m instead of 125 €/sq m) and on the other hand, by the considerably increased charges paid for photovoltaic installations resulting from the new law on the electricity from renewable energies.

The collector area installed in Greece in 2003 was by 6% bigger compared with 2002 and yet it could not reach the figures from 2001. An additional collector area of 215.000 sq m was installed in 2004 (+33% compared with 2003). This huge increase is explained by the fact that after the hard winter of 2003/2004 a lot of installations had to be repaired or replaced.

The Austrian market is very stable and well structured. In 2004 almost 190.000 sq m of collectors were installed, which is an increase by 8.3% compared with the previous year. The success on the market of solar thermal installations is due to the determination of the federal government to introduce a stable system for stimulating mostly the industry and commerce. By this system the investments for thermal solar installations are subsidized by up to 30%. The different federal provinces provide money to stimulate physical persons. Besides, a new campaign was launched in 2004 titled: "Climate: active solar heat", financed with 2.6 million Euro both by the public and the private sectors. Quite a number of European countries launched campaigns in 2000 and 2001 to promote the use of thermal solar installations and then they achieved their first successful results.

Thanks to the "Plan Soleil" Program in France in 2003, 188.000 sq m of solar collectors were installed (42.6% more than 2002). In January 2005 a new incentive scheme was adopted offering tax refunding for physical persons of up to 40% of the installation costs. With its 90.000 sq m of collectors installed in 2004 Spain became the fifth largest European market resulting from their national program "Plan de Fomento de las Energias Renovables".

It must be noted that the threshold of 10.000 sq m of installed collectors per year was reached for the first time in Belgium.

The Danish market, however, has been shrinking ever since October 2003 when the financial support was put to an end: there the newly installed collectors of 53.000 sq m in 2002 decreased to 43.000 sq m in 2003. Among the new member states Cyprus and Poland should be mentioned in particular. In 2004 Cyprus had 30.000 sq m installed and Poland - mere 29.000 sq m. The incentive pattern in Cyprus depends on the installation configuration (drinking hot water with heating, swimming pools, as well as reconstruction or installation of thermo-siphon installations), while in Poland there are no national programs for promotion or financial support of the thermal solar installations.

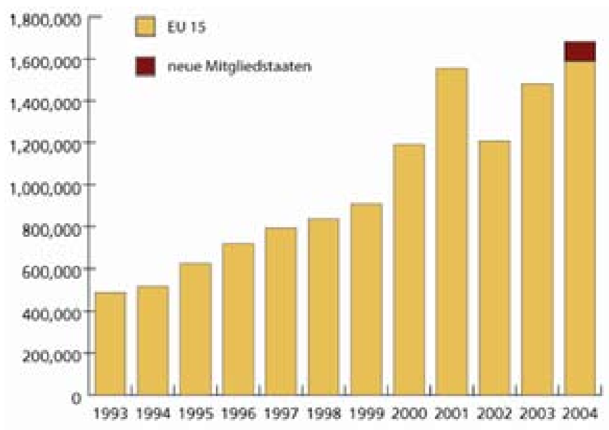
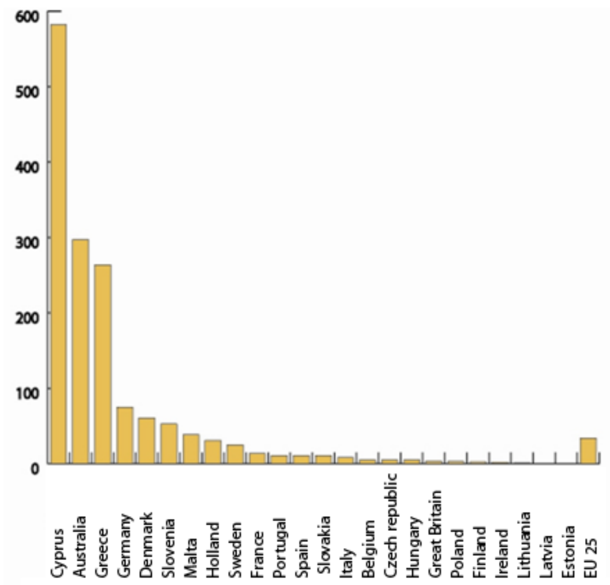


Fig. 2: Increase of the areas installed per annum in EU in m2 European Union in m^2 (Source: EurObserv'ER



Land	2003	2004'
Germany	750 000	780 000
Australia	176 820	191 494
Greece	161 000	215 000
France	97 628	116 915
Spain	83 272	90 000
Italy	55 100	55 000
Holland	49 686	58 304
Cyprus	30 000	30 000
Poland	26 500	28 897
Sweden	23 722	28 735
Great Britain	20 000	23 000
Denmark	19 000	20 000
Belgium	10 921	14 700
Portugal	10 000	10 000
Czech Republic	7 000	8 500
Slovakia	5 000	5 500
Slovenia	3 000	3 300
Malta	2 080	4 215
Finland	1 500	1 500
Luxembourg	1 500	1 700
Ireland	1 392	1 994
Hungary	1 000	3 000
Lithuania	400	500
Latvia	400	500
Estonia	150	250
EU 25	1,537,070	1,693,004

Fig. 3.: Area of solar collectors per 1000 inhabitants (Source: EurObserv'ER 2005)

Fig.3 gives an overview of the collector area per 1.000 inhabitants in different European countries. Cyprus is the leader and Austria and Greece rank second and third with 334 and 274 sq m per 1.000 inhabitants respectively. Germany ranks fourth considerably behind them, and the European average is 37.3 sq m per 1.000 inhabitants.

Germany is the leader in the thermal solar sector in Europe. According to data of the Federal Association of Solar Industry the turnover of 550 million Euros in 2004 maintained the level of the previous year compared with 390 million Euros in 2002. However the record of 2001 amounting to 650 million Euros could not be reached. Austria and Greece also profited from the market recovery in 2003: from 2002 to 2004 the Austrian collector manufacturing industry produced 330.000 sq m, 407.100 sq m and 500.200 sq m respectively. More than 3.200 workers are employed in the Greek thermal solar sector; the production capacity exceeds 250.000 sq m of collectors.

The actual dynamics and competition favor the end clients, to whom cheap products featuring high performance are offered. Of course, competition on the European market is still limited because the subsidies in the budgets of different national programs for support are only paid if the respective solar installations are tested by accredited national certification institutions. The certification process is expensive and because of that some producers cannot gain access to the foreign markets. For this reason the European solar Thermal Industry Federation (ESTIF) tries to introduce a European certification system (Solar Keymark), which should be acknowledged by all European certification bodies.

The objectives set in the "Campaign for Take-Off" were not achieved in 2003. At a European level the objective of 15 million sq m fell short of about 1 million sq m and this objective was only exceeded after 2004 resulting from the accession of the 10 new EU member states (see fig. 4).

Since almost 80% of the European market still depends on the situation in three EU countries (Germany, Austria and Greece), this leads to a certain instability of the market dynamics. Under these conditions it is very unlikely for the European Commission to achieve the objectives set for 2010 (the installing of 100 million sq m of collectors): firstly, because Germany is still far from the set objectives in spite of its leading role, and secondly, because the market for solar-thermal energy in many European countries is not developing rapidly enough (for example: Italy, Holland, Great Britain and Portugal).

In spite of the highly promising situation in countries such as France, Spain and Belgium the prognosis for 2010 in terms of installed capacity in Europe is for about 33 million sq m.

European Strategies for the development the Solar Thermal Industry

Climate preservation is an issue of national and international concern. Undoubtedly the most significant international agreement is the Kyoto Protocol whereby the industrial countries undertake to reduce over the period 2008 to 2012 their total emissions of the most crucial gases causing the greenhouse effect as much as at least 5% under their level of 1990. In 2002 Germany together with the other EU member states ratified the Kyoto Protocol, and within the framework for equalizing the obligations inside the EU it undertook by means of a 21% reduction before the first binding period (2008-2012) to contribute to the achieving of the common EU objective i.e. an 8% reduction. In 1997 in its White Paper for renewable energies the European Commission set out the objective to double the share of renewable energies in the EU internal energy consumption gross total by increasing it from about 6% in 1997 to 12% in 2010. (the EU aim of double increase). The absolute amount of the renewable energies, however, should be increased two and a half times compared with the previous amount in order to achieve a relative doubling. The biggest increase is expected from the utilization of biomass. The growth of the renewable energies should be ensured from 80% of the biomass whose share should be increased 3 times and its absolute share 3 times and a half, forced by the biofuel subsidization.

The other renewable energy carriers are expected to see a lower absolute growth, which, however, can lead to their higher relative increase than that of the biomass in some cases - for example in the wind and solar thermal installations. At a national level Germany has set the objective of achieving a double increase. The share of renewable energies has to be increased by 4% to 2010(2000:2%) and thereafter to continue increasing considerably.

In order to widen the dynamics of the solar - thermal sector a solid law frame at European level is needed. The European Union supports the solar thermal branch in a different way, mostly by directives and laws as well as by incentive programs (for example, Intelligent Energy Europe or the 6th Research framework program).

Moreover, campaigns for making the topic popular at different levels and last but not least measures for qualification and training are carried out. The market of solar thermal installation will be challenged to the utmost just when fitting of solar thermal installations will be regarded as natural on the part of the architects, the SHK-specialists and the consumers alike and when the price of these installations go down.

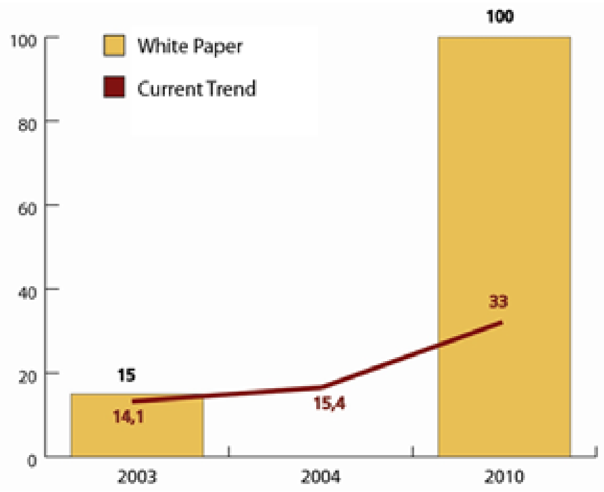


Fig.4 Directive on heating and cooling by means of renewable energies

The White Paper published by the Commission in 1997 sets a double increase of the share of renewable energies in the EU consumption, reaching up to 12% in 2010. The directive on the electricity obtained from renewable energies has set the task 22% from the electricity, respectively 6% from the total energy consumption to be produced from renewable energies. Apart from that, the directive on the biofuels foresees 1% of the total energy consumption to be covered by biogenic fuels. Thus the rest 5% of the 12% planned have to be made out from renewable energy sources for heating and cooling (biomass, solar and geothermal energy, also called RES-H), although this was a clearly set out objective. However, in the White Paper objectives in RES-H sphere for special sectors are set out. The RES-H development is also supported by the directive on the total energy efficiency of buildings. In this directive existing buildings with an area smaller than 1 000 sq m which have an enormous potential are mostly examined. This omission in the EU policy could reduce the chances of achieving the objectives set out about renewable energies. One should take into account that 50% from the energy consumption in Europe is used for room heating and water heating, both for personal and industrial needs. That is why a directive on the stimulation of heating and cooling by the use of renewable energies is needed and wished for in different fields. In 2004 ESTIF in cooperation with the European Renewable Energy Council (EREC) began organizing different groups by interests (such as industrial unions, research institutes, non-governmental organizations working in environmental protection; etc.) The majority of the member states have to support this in order to put such a directive into practice.

RES-H have a big potential although they are not still widely spread. They hold a different market share in the different EU country – members although it is not necessarily due to the availability of natural resources.

Solar Energy and Prospects for its Use in the Rural Regions

All this concerning the use of solar energy in the city is also valid for rural regions, but namely here, considerably more favorable conditions for the implementation of solar thermal installations exist to some extent: large, not overshadowed roof covers which have been used up to now for the installation of solar installations for electricity. Solutions concerning the rural regions lack in the solar – thermal field. Moreover the solar thermal installations represent an economic alternative taking into account the increasing expenses for fossil energy carriers when it is a question of heating and hot water providing. By the implementation of solar thermal installations mostly the enterprises for biologic agriculture can demonstrate their ecological claims with advertising effect.

Influences on the Environment

The solar energy can replace the conventional energy carriers such as coal, oil and gas and thus to reduce the pollution of the environment for ex. by the CO_2 emissions. Moreover the solar energy is not related to the risks of the nuclear energy. By using the solar energy the limited reserves of fossil resources can be saved in order to be used for other purposes in the future and not only for energy production through combustion. In comparison with the conventional energy production the solar technique does not require the expenses, risks and losses in transport and distribution because the decentralized production of energy makes its use possible immediately on the spot.

Even when one takes into account the energy used for the production and the permanent operation of solar installations which are partly depreciated from an energy point of view for a short time, solar systems contribute permanently to the saving of fossil energy carriers and to the reduction of the emissions, noxious to the climate. Having in mind the high responsibility for the environment, existing in Germany, the aspects, related to the protection of climate and nature, are an important argument for the buying of solar installations. Even the simple ones, which meet the technical standards for heating of water, can replace the non-renewable primary energies such as oil, gas or coal.

By using a solar installation a 4 – member household can save annually about 300 liters of boiler oil, respectively 300m3 of gas or 3 000 kWh. By the means of solar systems, covering part of the heating needs, the balance is improving more and more. One step forward are the so-called short-distance solar heating systems with long-term heating batteries which can cover with solar energy more than 50% from the total heating needs of whole towns and villages and which more considerably contribute to the fossil energy carrier saving.

Production technique for solar energy

Types of installations

The most important constructive section of a solar thermal installation is the collector which converts efficiently the solar radiation into heat. The heat is taken from the collector by a water or air stream, which bring it to the consumer (The term "collector" comes from Latin and means "battery"). The STI's (solar thermal installations) find the following application:

- Heating of household water
- Backup heating of premises
- Short – distance solar central heating
- Warming – up of the water in swimming pools
- Pre – warming of fresh air
- Solar cooling

Heating of household water and backup heating of premises

Most of the STI's are used for household water heating and sometimes for backup heating of premises. The biggest market for them are the buildings containing one and two households. Meanwhile, however, the number of the bigger buildings such as multi-household buildings, hospitals and hotels are equipped with collector installations is continuously increasing. The solar installations basically consist of the following components:

- Collector
- Pipeline (pipeline system)
- Solar installation with regulating unit
- Accumulating tank and heat exchanger

The heat from the collector is conducted along the pipeline to a well insulated water tank the heat carrier being an anti-freeze mixture of water and glycol. One heat exchanger separates the closed collector circulation circuit from the solar water tank. The solar station, consisting of a pump, safety appliances and a regulating unit ensures the right functioning of the solar installation in all operation modes. Whenever necessary, the upper section of the water tank can additionally be warmed-up to the desired water temperature by a heating boiler so as to ensure the supply at all times.

Solar thermal heating

The solar systems for central heating with seasonal accumulation are suitable for towns and villages with more than 100 residential units. The solar installation of this type has a large collector and a very big long-term water tank, which can be dug in the ground. The solar heat from the water tank is distributed to the consumer through the conventional heating system. The term "seasonal accumulation" means that the heat produced by the sun can be stored for a several-month period. In this way the time lag between the sun shining and the maximum heat consumption is compensated and the energy collected in summer can be used for heating in winter. The pilot installations implemented in Germany can cover about 50% of the total heat consumption (heating and hot water) of a given populated area.

Warming up of water in swimming pools

As a rule for warming-up of the water in open swimming pools plastic spring-beds without additional insulation are directly flowed over by the water in the swimming pool. Insolation of the absorbing spring-beds is not necessary since the desired final temperature (25 °C to 28 °C) is practically equal to the air temperature in conditions for swimming and the heat losses are respectively small. Solar installations for warming up of water in swimming pools are comparatively cheap and their use is economically profitable as of the present day.

Pre-warming-up of fresh air

Solar installations with air collectors can be used for pre-warming-up of the fresh air fed, especially for big buildings such as production premises in-door swimming pools and multi functional warehouses. Besides that the installations with air collectors can be used for supporting the functioning of air heating installations, for ex. in residential buildings. It is also possible for the excessive heat in summer to be used for water heating by means of air-water heat exchanger. Without any problems the air collectors can be used jointly with installations for heat extraction from the used air.

Air collectors consist of a ribbed absorber (aluminum profile with parallel channels) which is flowed over by air in the rib direction. The absorber is situated in a chamber whose posterior wall is heat insulated and the anterior one is covered with glass. The warmed air is fed by a fan into the ventilation or heating system. The installations with an air collector are comparatively cheaper than the collector installations for hot water since a water tank is not necessary. Besides that the requirements for the system technique are not so high because the air as a heat carrier cannot freeze or overheat.

The term "solar cooling" includes cooling and air-conditioning devices, in which the heat obtained in solar installations is used to produce low temperatures. On the one hand this can be done by refrigerating machines which by their function can be compared with a refrigerator and produce cold water for air cooling. In this case, collectors, through which water flows, are used for obtaining the heat necessary for the process. The other option is the following: the supplied air is cooled directly through appropriate consecutive drying and humidifying in which process air collectors are used. One of the solar cooling advantages consist in the simultaneous need for cooling and solar heat production since the t° in the premises increase on days with intensive sun shining (and a respective high energy output from the solar installation).

Mostly solar heat installations for hot water in one- and two-household houses will be discussed bellow.

Typical solar installation

As a rule the standard solar installations consists of one and the same components, shown on fig.5.

The solar circuit is separated from the hot water system and the additional warming-up. It is imposed by the fact that this circulation circuit works with water-glycol solution for freezing protection. The heat from the collector is transmitted to the drinking water through a heat exchanger. The heat exchanger of the collector circuit is situated down in the water tank, and the heat exchanger of the boiler-in the upper section (available for service section). In this way the solar circulation circuit always has the lower temperature in the water tank which ensures high collector efficiency.

The solar circuit always has a priority. This can be achieved by setting up of the regulation system and proper positioning of the sensors. In cases of insufficient sunshine, the additional warming-up of the boiler is turned on through the upper heat exchanger. Moreover, in winter the heat supply is interrupted (the advantage of switching to the water tank). When the specified temperature of the spare section is reached the regulation system turns off the pump for the water tank charging and turns on the heating pump once again. In summer, when necessary, the boiler is turned on manually. If in summer the turning on of the boiler and the backup heating are regulated by the external temperature, the damages appearing on the solar installation cannot be detected because of the permanent presence of hot water.

A flat-plate collector, a vacuum tube collector and an evacuated flat-plate collector will be described below, and some other types of collectors will be mentioned at the end of the section.

Symbol	Description	Function
	Collector	Heat production from solar radiation
	Water tank	Heat accumulation, storage and release
	Heat exchanger	Heat transfer between liquid media
	Expansion vessel	Pressure buffer for different operation modes
	Safety valve	Prevention of overpressure
	Non-return valve (inertia brake)	Prevention of flow in the wrong direction
	Circulation	Circulation of the required flow volume
	Pump Pressure Indicator	Pressure indication
	Temperature indicator	Temperature indication
	Automatic quick acting air valve	Autonomous ventilation
	Solar regulation	Circulation pump regulation

Fig. 5 Typical solar installation components

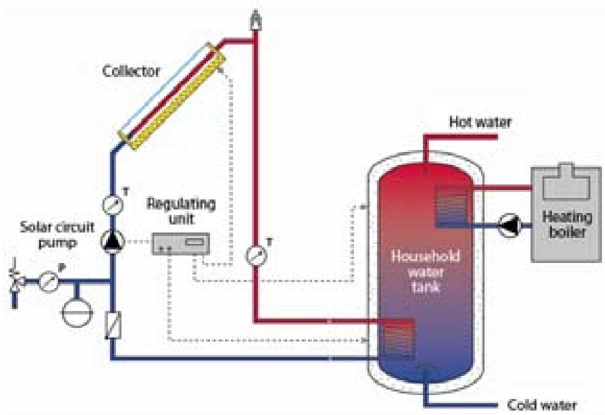


Fig. 6 Typical standard solar installation

Flat-plate collector

All flat-plate collectors, offered on the market, consist of heat-transfer plates with integrated tubes (absorber), frontal glass shield and heat insulation of the lower and lateral walls. These components are assembled in a light frame structure (see fig.7).

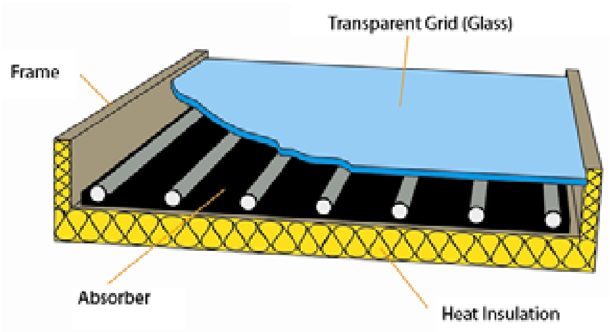


Fig. 7 Typical Flat-plate collector design

The collector functions on the principle whereby the short-wave sun rays penetrate though the glass and in contact with the collector they are transformed in long-wave radiation (heat) which can only partially be radiated to outside. That is why the main section of each collector is the absorber.

Absorber

In the collector the absorber functions as a garden hose, situated in the sun, and translates the sun rays into tangible heat. In a typical collector the absorber is made of copper, copper-aluminum alloy or chrome-nickel steel with black coating. When the sun rays come in contact with the absorber most of them is absorbed and a small section is reflected. The absorber radiation produces heat which is transmitted to the heat-transfer tubes in the metal plates.

A heat-transfer liquid absorbing the heat flows in the tubes. The way of connecting the tubes with the absorber plates is of a special importance for the optimal heat-transfer. Besides having to correspond to these mechanical requirements the absorber has not only to absorb well but also to emit little from its heat. These radiation losses are called emission losses. An absorber with a normally black surface emits heat almost freely i.e. it has a very high emission coefficient. This heat emission is impeded by the glass since the former is long-wave radiation, but in the same time it warms the glass which causes big heat losses. By installing a second glass shield these heat losses can be reduced but this would limit the light filtration as well. In this case the selective absorber coating can help. It reduces the emission losses by 10-15% in comparison with the normal black absorbers. This absorber coating, specially worked-out, has established itself among manufacturers.

Body and glass lid

In order to protect the absorber from atmospheric influences and heat loss it has to be coated with glass and insulated with special material or by means of air-evacuation. The solar protection glass has to contain a little iron so that it can have the highest possible light-transmission capacity.

Its resistance to pressure is about 700N/mm2. Compare with: fiber-glass reinforced plastic has a resistance to pressure of about 250 N/mm2. The protection glass is hardened and prestressed in order to resist for ex. to hail. This glass guarantees additional safety in case of breaking because it splits into a lot of particles which reduces the danger of accident. The collector body has to incorporate the different components in such a way that the heat losses during operation could be minimal. Differences between the absorber temperature and the ambient one in the range of 40K are normal and require very good insolation laterally and posteriorly. The good collector is characterized by minimal heat losses. Flat -plate collectors are manufactured in different sizes. The active absorbing surface translating the radiation into heat is the most important for energy production. The body collector area (gross area), of the glass lid (finish surface) respectively plays another role in the technology. The gross surface determines for ex. the need of place on the roof; the finish surface is the basic surface for collector efficiency. Another factor for high energy production is the opportunity of small mass heating (0.4 to 0.6 l/m2 heat-transfer liquid) which gives the opportunity for a quick reaction to the changing radiation.

Physics and heat engineering

Energy flows

The visible radiation penetrates through the glass almost without obstacle since in the visible range it has a high transmission capacity - over 90% (transmission). The black absorber translates the visible radiation into heat which leads to a strong warming of the absorber (absorption). Since every warmed body emits heat emission losses arise. (emission)

Because of the minimal transmission capacity of the glass for infra-red (IR) waves the infra-red emission can only leave the collector partially (greenhouse effect). The different emission qualities of the normal and selective absorbers show that the latter are considerably more suitable for solar heat production.

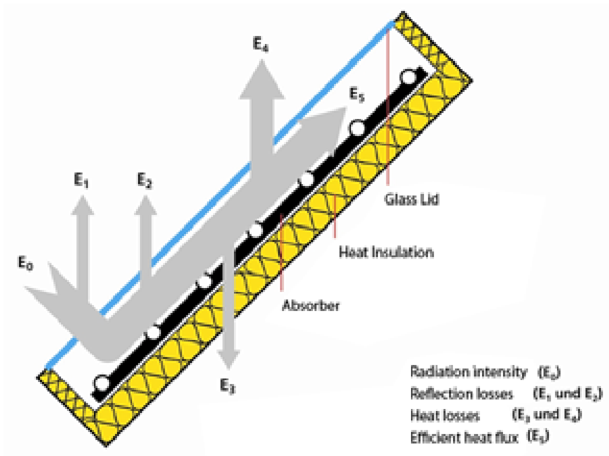


Fig. 8: Energy flows in a flat-plate collector

Collector power

The power of a given collector is determined on the basis of profit and consumption. The profit is the emission energy received. The losses are optical and thermal. In order to calculate the profits under the form of radiating energy we need the absorption coefficient α, the transmission coefficient τ, and the radiation intensity EG (radiation strength).

Optical losses describe the share of the solar radiation which cannot be absorbed by the absorber. For their calculation we need the product of the transmission coefficient (τ) and the absorption coefficient (α) because they reduce the radiation intensity (EG).

The heat losses described in a simplified way depend on the temperature difference between the absorber and the environment, as well as on the collector construction. In order to show the structural effect on heat losses, the losses from heat conductivity, convex ion and emission are united and are represented as an effective coefficient of heat conductivity, respectively the U-value before k-value (keff). The product of this value and the temperature difference between the absorber and the environment temperature (Tabs minus TUmgeb) represents the heat losses (QVerl).

Graphic characteristic of the efficiency

The representation of the collector efficiency can easily be done on the one hand from the energy balance between the optical, respectively thermal losses, and on the other - the profit from absorbed radiation. In a more simplified way the collector efficiency can be expressed by the correlation between the useful heat energy and the solar energy, coming in contact with the collector. The useful heat intensity is equal to the collector power (QKoll) and is obtained by subtraction of the losses from the profits. The relation to the radiation intensity represents the collector efficiency (η).

This simplified calculation of the collector efficiency gives respective characteristics. It is clearly seen that by increasing the temperature difference (ΔT) the efficiency falls.

Fig.10 shows the optical losses which do not depend on ΔT as well as the heat losses which increase by ΔT increasing.

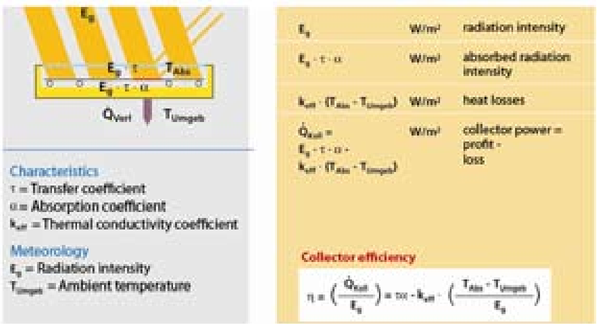


Fig. 9: Collector energy balance and efficiency

Stagnation temperature

When heat under the form of useful energy is not extracted from the collector the temperature rises until the moment when outputs and losses become equal. This means that the whole absorbed radiation intensity is lost because of heat losses. In this case heat intensity cannot be given anymore: therefore the efficiency is equal to 0(η=0). This stagnation temperature is also called temperature of standstill because during the temperature increase a state of standstill (rest) is reached.

Heat production

In order to obtain useful energy from the collector heat has to be conducted through the solar circulation circuit. The extraction of this useful energy depends on the production conditions of the collector. We have to know the values of the heat transfer liquid: specific heat capacity CP and specific density for making the calculation. After determining the production conditions: entrance temperature TE , exit temperature TA and volume stream v we can calculate the collector heat intensity. When this heat production is observed during a given time period the respective heat output is obtained. If we calculate the correlation between the collector heat output and the solar radiation during this time we obtain the collector efficiency for the respective period.

By means of these values we can calculate both the temperature difference ΔT and the volume stream v which are of great importance for the practical use of the installation. The optimal temperature difference should be about 5-10k, and the volume stream in the collector circuit- 30-50l/m2.

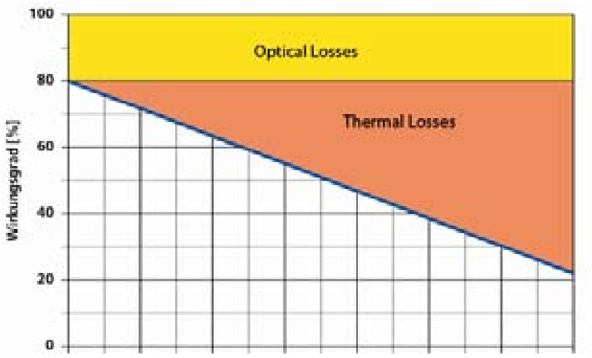


Fig. 10: Efficiency Chart

Vacuum tube collector

The absorption effect in the flat-plate and the tube collector is identical. In principle differences are in the heat insulation.

In the tube collector the absorber is built-in air-evacuated glass tubes for reducing heat losses. The vacuum possess good heat insulating qualities (the flask principle), heat losses are almost completely reduced. Even at absorber temperatures of 120° and above the glass tube remains cold outside.

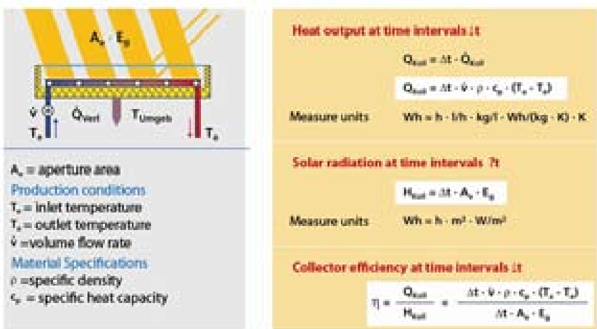


Fig. 11: Collector heat production and efficiency

Glass Tubes

The vacuum tube collectors consist of glass tubes because only this structural form can resist to the high external air pressure. The forces, arising in the nearly complete vacuum are very well taken in by the high pressure resistance of the tube form. In the modern vacuum tube collectors the remaining pressure is from 5 to 15 mPa. Compare with: the atmospheric air pressure on the earth surface is about 1.000 hPa.

Two basic differences concerning the glass have to be underlined:

- Boron-siliceous glass (CORTEG ,DORNIER -PRINZ)
- Sodium glass (Thermomax-tubes, Sydney-tubes)

The clients often fear that vacuum and glass are two very sensitive materials but we can give the following argument: The high atmospheric pressure on the glass tube causes considerable pressure and sliding resistance thus the glass loses the qualities in question and can be regarded as an extremely hard material. As the time passes, the big pressure difference from the ambient pressure leads through the penetration of hydrogen from the air to the decrease of the insolation effect. Producers react to this fact in a different way: on the one hand change of the air-evacuated tubes is simply recommended, and on the other - the penetrating hydrogen can be trapped in a chemical way by means of special, so-called getter. In Freiburg solar house air-evacuated collectors which have only about 80% from their initial outputs at the moment have been working since 1978.

Heat Transport

The heat transport from the vacuum tube collector can be carried out in two ways:

- Direct, flow: The heat transfer fluid flows directly through the absorber under vacuum
- Thermo-tube technique: The heat transport from the absorber to the heat transfer fluid is accomplished in a closed tube.

The vacuum tube collectors with direct flow can be installed independently from their installation position. This means that the vertical links along the building façades and the balcony rails are as possible as the horizontal installation on flat roofs. In these air-evacuated collectors the heat transfer component passes or through a tube-in-tube system to the glass tube bottom and flows in inverse flow absorbing the absorber heat or flows through a U-shaped tube.

The other heat transport technique uses additional heat transfer and is called Heat-Pipe air-evacuated tube. In this type of collectors the absorber is connected by a heat transfer metal link with Heat-Pipe. The heat tube is full of alcohol which evaporates at low temperatures because of the sub pressure. In the upper section of the tube the heat, liberated at condensation, is transferred to the heat transfer liquid passing along it. Under the gravity effect the cooled and condensed alcohol flows backwards into the heat tube for a second heat absorption. For the functioning of this process the tubes have to be installed under a gradient of at least 30º. The Heat-Pipe air-evacuated tube is offered with one dry and one wet link of the heat tubes to the solar circuit. In the first link the heat tube is received by a condenser. The heat transfer is carried out by the condenser and a clamp link to the heat transfer liquid. This gives the opportunity for changing defective tubes without emptying the solar circuit. There is an advantage in the installation too: The tubes can be installed at the end of all operations after the finishing of the preliminary work, including the hydraulic pressure test of air tightness.

In the case of the wet link the condenser is immersed in heat transfer liquid and transfers heat energy directly to the liquid flowing over it. Here, the advantage is that additional heat transfer of the clamp links leading to higher absorber temperatures, are avoided. Some producers use water as heat transfer component instead of alcohol. The tests, done up to now, do not give advantage to either of both principles.

Heat Storage

In solar installations for hot water for one-and two-household building two-valency water tanks of 300 to 500 l volume and two heat exchangers are used: a lower one for connection with the collector circuit for water solar heating and an upper one for connection with the heating boiler for backup heating. The different density of the hot and cold water leads to temperature demixing in the water tank. The lighter hot water is collected in the water tank upper section, and the heavier cold water - in the lower one. The narrower and higher the water tank, the more expressed this temperature demixing is. In the narrow water tanks the temperature equalization between the layers outside the storage periods is limited. The cold lower section makes the collector work with high efficiency even during periods of limited sun radiation. The highly efficient solar water tank goes with good heat insulation. It has to be 10 to 15 cm thick, including the water tank bottom, to adhere well everywhere (otherwise there are convection losses) and to be made of materials free of FCKW and PVC.

The link elements of the heat exchanger for additional warming up and exhaustion of hot water have to be tapped from the insulation in the lower section of the water tank, if possible, in order to avoid the damaging of the heat insulation in the upper hot section and thus to reduce the heat losses.

If because of the water hardness strong precipitation of limestone is expected the temperature in the water tank has to be limited to about 60°C. Otherwise the heat exchanger surfaces could be covered with limestone since it precipitates at temperature higher than 60°C. A layer of only 2mm reduces the transferred heat of the heat exchanger by 20% and in cases of a 5mm layer it can reach up to 40%. The increase of the temperature difference between the inlet and the outlet by more than 15K could be a sign of a heat exchanger, covered with limestone.

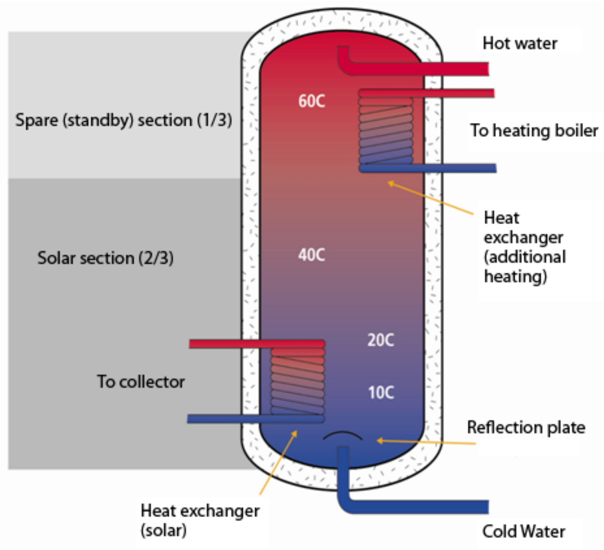


Fig. 12: Solar tank with two heat exchangers

Tank connections

Cold water: A reflection plate, installed in the water tank above the cold water inlet, prevents the mixing of the entering cold water with the hot water in the upper layers and the breaking of the demixing in the water tank.

Hot water: In the conventional water tanks the hot water is drawn by means of a pipe, going upwards. After closing the place from where the water is taken away the remaining hot water in the tube is cooled again and a cold water waterfall is formed, reaching the upper water tank layers. This leads to the breaking of the temperature demixing and may cause heat losses in the range of up to 15% from the total water tank losses. That is why the better way is the following: to put the tube for taking the hot water away inside the water tank from the top to the bottom and to tie it with a bottom flange. Thus the additional heat losses, caused by the insolation breaking of the water tank upper section disappear. Since the water temperature can be 60ºC and more it is advisable to put a thermostat mixer whose function is to limit the water temperature in the tube to the desired level. Thus a protection from burning is ensured and unnecessary heat losses are avoided. An additional installation of a thermometer behind the mixer is recommended for correction of the set up temperature. Since the water mixer is susceptible to pollutions there has to be a filter in the cold water pipe.

Heat exchanger: The links of the heat exchanger to the solar circuit and the circuit for additional warming up have to be put through a bottom flange (cold water zone in the water tank) for reducing heat losses. The heat exchanger for the solar circuit is situated in the lowest possible place of the water tank so that the water tank content could be heated to the bottom. The situation of the heat exchanger for additional warming up in the upper water tank section guarantees quick heating of the spare water volume without impeding the collector circuit to conduct efficiently small quantities of solar heat to the cold water tank section.

Circulation: Circulation pipes are often installed in order to quickly supply hot water to the consumption places in long pipe nets. The circulation reduces water consumption since flowing out of the unnecessary cold water at the consumption place is avoided. The circulation pipe has to be very well heat insulated for reducing heat losses. In all cases the working time of the circulation pump has to be limited which can be done by means of a breaker with clockwork. The backward tie of the circulation circuit is connected to the water tank at about 2/3 of its height. A disadvantage of the circulation is the fact that it influences the temperature demixing in the water tank. In new one- and two-household houses the circulation pipe can be spared by means of short pipes, good heat insulation and a small tube diameter.

Tank material

The pressure tanks are either enameled or made of stainless steel. The stainless water tanks are comparatively light and do not require maintenance but are considerably more expensive and, at the same time, susceptible to water with high chlorine content. Compared with them the enameled steel water tanks have a potential corrosion problem because there is always some air dissolved in the drinking water whose oxygen can have corrosion effect. Since in enameling there are a certain percentage of defective spots, caused by manufacturing or transport, the unprotected steel can be corroded. That is why the enameled water tanks have to be equipped or with a magnesium anode or with an anode with electricity from a lateral source. Magnesium is a base element and because of that a galvanic element is obtained. Throughout the years the magnesium dissolves and prevents steel rusting - that is why the magnesium anode is called a sacrifice anode. When using an anode with electricity from an external source, corrosion is prevented through the electric voltage between the anode and the water tank material; the anode taking the function of the base metal. The advantage of this method is that the anode does not dissolve and the power consumed is less than 1 Watt.

Layered Water Tank

A special form of heat storage is carried out in the so-called layered water tanks. On principle the solar temperature level reached (for ex. 45ºC in the supply line of the collector circuit) is supplied without mixing in the section with the same temperature. Thus the solar heat will be immediately available at the level of the temperature in use without heating the whole water tank first. The water tank lower section remains cold and the collector can operate with high efficiency and this way it can use even the minimal sun radiation.

Solar Station and Regulating Unit

For simplifying the erection of a solar installation the main components and fitting are united in the so -called solar station and are offered as such, installed as a kit. For example, a collector pump, a deaeration component, a flow meter, a gravity brake as well as control and protection devices (thermometer, manometer, safety valve) are integrated in the solar station. For reducing heat losses the solar station is heat insulated – it has a regulating unit, installed outside the thermal insulation. Similar to the heating installations there is also a leading-in and a leading -out pipe in the collector flow. The hot outlet collector pipe which leads to the water tank is mentioned as leading- in pipe. The cold supply pipe from the water tank to the collector is the leading -out pipe respectively. The collector pump, the manometer and the safety valve, as well as the link for the expansion vessel are situated in the reflex section of the collector circuit which leads to limited thermal leading of the components. The expansion vessel serves as a pressure buffer at different operation modes i.e. it takes in the volume expansion of the heat transfer component in heating while the safety valve must not function at normal working regime. The flow meter is also situated in the reflex section of the collector circuit. This structural element is known also under the name Taco-Setter (manufacturer's name) and, first of all, serves for reading the volume flow rate. Most of all the flow is limited by means of the revolution rate of the collector pump; on principle fine adjustment is not necessary. A reflex valve gravity brake) has to be put in the leading-out pipe of the collector circuit. Since only the thermal push is not enough for opening the valve the gravity brake prevents the water tank cooling through the collector when the pump stops (mostly at night) One has to pay attention to the fact that the valve has to be put in operation i.e. it should be open.

Regulation

The principal task in the regulation of a solar installation is to regulate the collector pump so that the solar energy could be used in an optimum way. In most cases it is a question of ordinary electronic regulation of temperature differences. For the regulation of the temperature differences of an ordinary solar installation 3 temperature probes are necessary: one probe, installed in the hottest place of the solar circuit (at the collector release outlet), the second temperature probe is situated in the lower water tank lower section at the height of the solar circuit heat exchanger; the third sensor is situated in the water tank upper section. By means of the temperature probes the regulating unit follows the temperatures at the collector outlet and the water tank, and, by a relay turns on the collector pump when the temperature at the release collector hole (leading-in pipe of the solar circuit) is higher by several degrees than the temperature in the water tank lower section. The loading of the water tank is ceased by turning off the circulation pump when the temperature difference between the release collector hole and the water tank lower section reads the reaching of maximum temperature. The setting up of the right temperature difference for turning on depends on different factors. The principle is the following: The longer the pipe of the collector circuit, the bigger the temperature difference, respectively the delay of the turning on has to be chosen, the standard setting ups are from 5K to 8K. The temperature difference for turning off is usually about 3K. By the way the efficiency depends on the situation of the temperature probes. The collector probe is fixed or on the absorber collector tube or directly on the absorber near the collector inlet. In all cases it is important for the temperature probe of the collector drainage hole to read the absorber temperature at stagnation of the installation, i.e. when the pump is turned off. The temperature probes in the water tank are usually installed as immersing or adhering probes. Since the resistance characteristic depend on the material and the temperature, temperature probes made by different manufacturers, cannot be replaced randomly.

Safety Aspects

Each closed heating circuit is equipped with a protection structural group. A group of this type consists of an expansion vessel and a safety valve. The expansion vessel takes in the volume expansion of the heat transfer component at heating. The safety valve is not operated at a regulation regime - it is installed as additional protection. It opens when a determined pressure is exceeded in the heating system. At a regulation regime such a thing could not happen because the expansion vessel compensates the pressure increase. This safety valve is included in all conventional heating and hot water installations. In the collector circuit of the solar installation the protection structural group has an additional function: one bigger expansion vessel guarantees the so-called natural safety of the collector device. In a conventional heating system the heating boiler can be turned off when heat is not consumed. In a solar installation the collector pump transferring heat to the water tank can be turned off but the collector itself remains permanently exposed to the solar radiation. If, for ex. the pump is out of order (or during summer holidays) heat is not consumed, stagnation temperatures of above 200°C can arise. Such overheating lead to rather high loading of the material because of the heat transfer fluid evaporation and should be avoided. If all the heat transfer liquid is evaporated this could lead to rather big pressure increase. That is why the expansion vessel of the solar installations is chosen with such dimensions so that it could take in the whole content of the heat transfer component in the collector circuit. During evaporation in the collector the steam bubble, quickly increasing inside, pushes the liquid, still non-evaporated, from the collector to the expansion vessel ("dry boiling"). In the conditions of continued heat coming in the dry steam, remaining in the collector minimally increases its volume so that the pressure increase remains limited.

When the heat coming in decreases the steam condenses and the heat transfer component is pushed back from the expansion vessel to the collector.

Legionellae

The discussion about legionallae existence in relation with the solar installations is conducted. Legionallae are rod-shaped bacteria which exist everywhere in fresh water. They reproduce the most at temperatures between 25°C and 55°C; at temperatures above 60°C they are not viable anymore. If they are taken in through the stomach and intestines they are harmless; but they can cause infection by inhalation. Legionallae are found in dangerous concentrations mostly in air-conditioning installations for air humidification and Jacuzzi baths as well as in large installations where the hot water remains for a long time (for ex. in hotels or hospitals with big water tanks). However big concentrations are measured in electrical devices for teeth and mouth wash, and in showers as well. On the one hand the legionaella problem should not be considered as inoffensive. On the other hand, it cannot be immediately agreed that the use of the ecological solar energy itself at optimum water temperatures from 45°C to 50°C is discredited and can partially be classified as dangerous technique, even more so that there is no difference between the solar and conventional hot water installations concerning the infection risk. Generally, fine pulverization showers should be avoided and the circulation pipes have to be as short as possible.

Dimensioning and Energy Efficiency

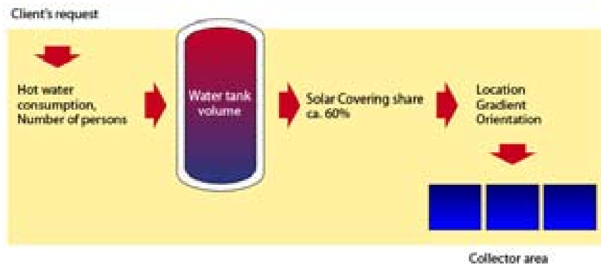
In principle, it should be noted that the dimensioning of the collector installations is first of all determined by the respective need of hot water. In summer rather big installations produce excessive quantities which cannot be used and because of insufficient loading they work in an ineffective way which is related to comparatively low specific solar bearers. In hot water solar installation firstly one has to take into account the hot water need of the respective site, and in backup heating installations of premises the heating need plays the main role. In this respect there is a difference between the calculation of collector installations and the dimensioning of PV-installations.

The most important elements of a solar station are the collectors and the water tanks which have to be coordinated with each other in the optimum way. The rest of the structural sections of the collector installation have to be fitted to these 2 components. Fig.13 shows the sequence of the main steps in designing the hot water solar installation.

Hot water quantity requirements

The water consumption of a household determines the energy consumption for hot water production and that is why it is an important value for calculating of the hot water solar installations. The average hot water consumption is between 40 and 50 l per person a day. The main thing in designing a solar installation, however, is the actual consumption which can vary in a large range between below 30l and above 120l. In calculating the consumption one has to check whether the client strictly uses the opportunities for saving drinking water (for ex. by saving water fittings) since less water consumption allows less solar installations and, lower investment expenses, respectively. The actual hot water consumption of a household can be determined by water meter, installed on the cold water supply system of the water tank which must be read by the client every day throughout several weeks. The installation of the water meter can be done by a SHK-enterprise and the respective expenses to be taken into account in case of buying a solar installation. For designing new buildings, where calculation is not possible, one should compare the values measured in similar residences, with similar comfort level, respectively, and to meet the expected consumers' behavior. On principle the question for family planning and the future use of the building has to be discussed since the operation life of a solar installation is more than 20 years.

1x hand washing (40°C)	3 l
1x shower (40°C)	35 l
1x bathtub (40°C)	120 l
1x hair wash	9 l
Cleaning	3 l per person a day
Cooking	2 l per person a day
Dish washing (50°C)	10-20 l per person a day



Consumption	Water in liters (l)
Low	25-35
Medium	35-65
High	65-95

Table 2: Hot water (45 oC) average amount needed per person per day

Depending on the consumers' behavior and the household appliances the average values for hot water (45°C) consumption per person a day are obtained.

One must accept as tentative value the average hot water (45 °C) quantity per person a day is 40 l plus 5 l for a washing machine (3 l) and a dish washer (2 l).

Accumulating tank capacity

The water tank has to contain water quantity 1.5 to 2 times as bigger as the necessary daily quantity in order to also cover days with limited sun radiation without backup heating. A typical volume of the water tank in the range of 300-400l is obtained for a 4-member household with average hot water (45°C) consumption of 50l per person a day.

The choice of a 300-l water tank (necessary quantity x.1.5) presupposes slight reduction of the hot water consumption without breaking the comfort, for ex. installing of flow-limiting components, economical shower heads, thermostatic fittings etc. This has a positive additional effect of the lower water consumption and leads to lower taxes for tap water. The choice of a 400-l water tank (necessary water quantity x2) gives the opportunity for a higher solar share in covering the needs, resp. for additional turning on of a washing machine and/or a dish washer and, at the same time, the electricity consumption of these appliances is reduced.

Collector Area

The size of the necessary collector depends on the solar share, wished for covering the needs, on the sun radiation and the collector type, as well as on the whole system efficiency. The solar energy share in the total energy demands for hot water production is called solar covering share and is usually from 50% to 70%. At the end the size of the solar covering area is determined by the client's investment readiness. On the basis of regional differences the annual sun radiation depends on the solar installation location. Besides that the inclination and the orientation of the collector area influence the annual amount of the striking radiation. Not only roofs with southern orientation are suitable for the installation of solar elements (see also section II.3). An increase of the collector area for ex. by 10% can be defended economically and compensates the lower yields, caused by the deviation of the optimum orientation. An existent overshadowing, for ex. by neighboring buildings and construction sites, reduces the radiation and the installation yields, respectively. That is why the overshadowing of solar elements should be avoided; in any case the influence of overshadowing in the collector installations is not as big as in the PV-installations.

All the elements of a solar installation show heat losses. All the installations transform the radiation energy into heat less or more efficiently. The system efficiency is the correlation between the solar yield and the radiation amount (insolation), describing the efficiency of the whole solar installation for a longer time period (usually a year). The solar installations with a flat-plate collector usually have a system efficiency of about 35%; for air vacuum tube collectors this value is about 45%.

In hot water solar installations for one-and two-household houses a collector area of about 1-1.5 m2 per person (tentative value) is necessary, in bigger installations (with more loading) in multistory building this value is between 1.5m2 and 2.5m2 for a home.

Output and solar covering share

The solar installation output is influenced by different factors. They are the different radiation in the different regions, the orientation and the eventual overshadowing of the collector area, collector efficiency, the solar installation loading, the chosen scheme of the system, the heat losses of the water tank, etc.

Table 3 shows the annual energy output of a typical hot water solar installation for a 4-member household in different towns and cities in Germany, determined by T*SOL simulation program. The calculations are made on the basis of the following values for one-family houses:

Hot water needs:	180l per day
Roof orientation:	southern, 40° gradient
Collectors:	2xRSK 18/14
Absorber area:	4.7m2
Water tank volume:	300l

Location	Energy output [kWh/a]	Solar covering [%]
Sylt	1.959	58
Hanover	1.783	54
Berlin	1.962	59
Frankfurt am M.	2.114	62
Wurtzburg	2.045	61
Freiburg	2.328	68

Table 3: Output and solar covering share of a hot water solar installation in different towns and cities

The annual energy output is between 1.800 kWh/a in Hanover and about 2.300 kWh/a in Freiburg where there is a lot of sun shine. This causes specific energy output in the range of 380 kWh/a(m2.a) to 490 kWh/a(m2.a) related to the collector area. The solar covering shares are between 54% and 68% and the conclusion is that the respectively dimensioned solar installations can cover over 50% from the hot water needs even in regions where there is little sunshine.

In solar installation with big dimensions - particularly during hot months - a considerable heat quantity is obtained which cannot be used for hot water production and as a rule cannot be stored. This reduces the installation economic efficiency. That is why too big solar installations are not recommended. On the other hand there is a group of clients who look for installations with big dimensions on purpose in order to continue the full covering in summer in the longest possible time during the transitional period. When preparing the order for these clients attention should be paid to the excessive energy in summer, underlying that does not mean wrong functioning of the installation. In relation to the safety technique in such a dimensioning there are no fears since the measures for natural safety of the installation have to be applied in all circumstances.

Simulation Programs

For determining the solar thermal installation parameters a lot of simulation programs exist which are partially different in relation to the implementation sphere, the functional range, the accuracy of calculation and service comfort. By such programs heat flows, temperatures and the installation output can be calculated as well as the solar covering shares, the efficiency of different solar installations, respectively systemic configurations of the respective locations. In principle by using simulation programs one has to take into account that the results from the calculations can only be as precise as the input consumer data and the simulation method allow. The atmospheric data quality, necessary for each simulation, influences the accuracy of the output prognostics. By comparatively simple for application programs and precise input data the accuracy of the output prognostics reaches 10-15% approximately. Simulation calculations with more complicated calculations can show the actual measured solar installations output with up to 5% accuracy.

Conditions for the installation operation

The whole solar irradiation striking a horizontal or an inclined surface is called global radiation. In relation to the horizontal surface the global radiation is the sum of the direct solar radiation and the diffused sky emission: a surface, inclined toward the horizon catches also the solar radiation, reflected by the earth surface. The solar radiation intensity specific for the surface, is marked as radiation intensity and is measured in Watts per square meter (W/m2). If the moment values of the radiation intensity for a given time period are summed up, the solar radiation energy, striking the surface, is obtained. This value is called insolation radiation, is measured in kilowatt hours per square meter (kWh/m2) and is usually mentioned as daily, monthly or annual sum.

The global radiation intensity on the horizontal line and the respective insolation sums allow the comparison of different locations of the installations from meteorological point of view. The most important values for the solar installation evaluation are the radiation intensity and the insolation intensity in the collector and module plane. The height of the sun, respectively the angle of the sun height, is the angle which the observer sees between the sun center and the horizon. The values of this angle are between 0º and 90º, 90º being only on the equator. The highest position for the day is at noon, when the sun is orientated southward (for the northern hemisphere). Fig.14 shows the sun orbit throughout the year for a place in southern Lower Saxony (52º northern latitude). There the sun height angles at noon are approximately 15º on 21 December and about 61º on 21June. The azimuth angle of the sun (solar azimuth) is the angle between the geographic southern direction and the vertical projection of the straight line observer - sun on the horizontal line. The sun azimuth describes the deviation of the sun situation from the southern direction and is usually accounted for as negative in the east and as positive in the west. That is why the azimuth angle values can vary between 0º and +180º.

The perceived radiation intensity and the insolation sum depend on the tilt and the azimuth orientation of the receiver surface.

Maximum insolation is obtained in solar installation which is permanently directed to the sun and is vertically lit by it at any moment. The automatic direction has some disadvantages: (high cost, expenses for drive energy, maintenance costs) and does not lead to high energy output. Fig.15 shows the annual insolation depending on the tilt angle and the azimuth of the receiver surface for Hanover, the data percentage being valid for maximum annual insolation 1.100 kWh (m2.a). For Hanover the maximum annual insolation is obtained on receiver surface with southern orientation and a tilt angle of 35º; a vertical southern façade receives 30% less solar insolation. All surfaces, orientated within a 95% marking, are suitable for erection of a solar installation because the minimum output will be 5% for the deviation from the maximum orientation. This range includes all the surfaces, orientated between southeast (-45º) and southwest (+45º) and a tilt between 20º and 50º. Tilts less than 20º can cause problems since the cleaning action of the rain is not going to be enough and the overshadowing snow is not going to be able to slide or is going to slide hard on the solar elements. The use of vertical façade surfaces in spite of the limited insolation can be advisable since the solar elements replace the expensive conventional structural elements for external covering of the building (for ex. stone, stainless steel, special glass, etc.) and the construction costs saved reduce the investment for a solar installation.

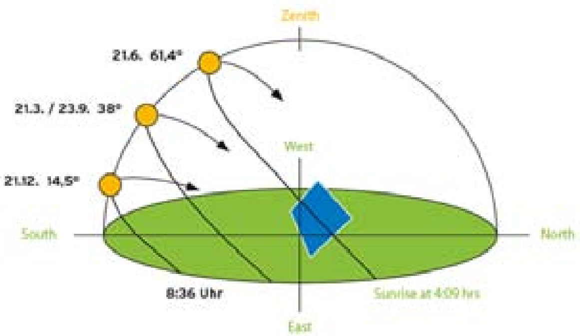


Fig. 14: The Sun's annual path at 52o northern latitude

At the external edge of the earth atmosphere the solar radiation (on a surface, situated vertically to the rays' direction) has an average intensity of 1.370 W/m2 – this value is called a solar constant. On its way to the earth surface the solar radiation is diffused by the atmospheric components and is partially absorbed by them, besides that a part of it is reflected by clouds. Because of these processes the intensity density of the solar radiation is reduced, besides that the earth atmosphere influences the radiation spectrum.

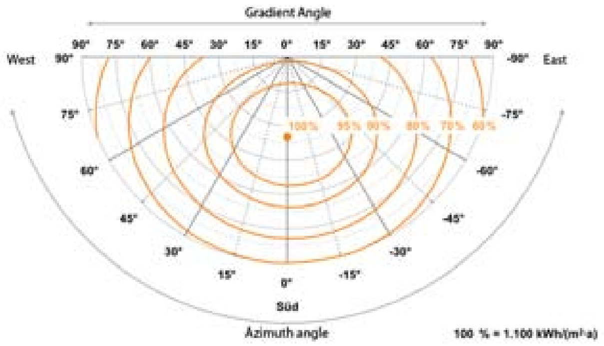


Fig. 15: Annual insolation depending on reception area orientation

The solar radiation, reaching the earth surface from the sun disc, is called direct solar radiation and is perceived as sun light. When the direct radiation comes to an obstacle a shadow is made. The light, present in the shadow zone, is due to the diffused rays which come from the entire hemisphere directions and are perceived as sky light. The global radiation on the horizontal line represents a sum of the direct and the diffused radiation: the inclined surfaces additionally catch the sun rays reflected by the soil.

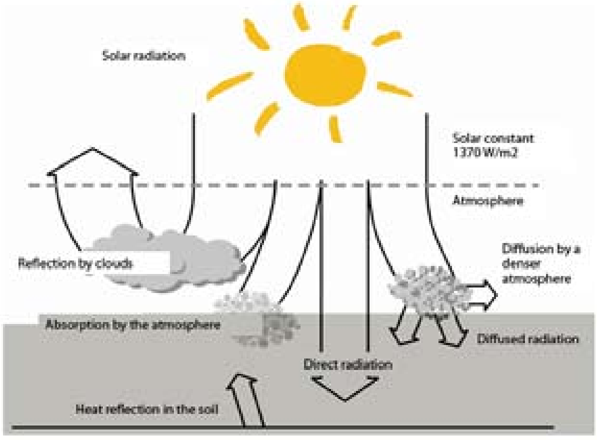


Fig. 16: Atmospheric influence of the insolation over the land

On cloudless days the share of direct radiation in the global radiation is big, while in fogged atmosphere (with comparatively small visibility) and a clouded sky the diffused share is increased (fig.17). For the active use of the solar energy the most accurate data for the radiation intensity and the insolation sums of the global and diffused, respectively direct radiation, are necessary. These data can only be obtained by measuring. Since the radiation conditions throughout the different years are different several annual average values of the insolation sums are necessary. In an ideal case such detailed data for the radiation, measured in the vicinity of the future solar installation should be available in order to design a solar installation in the right way and to foresee its energy output.

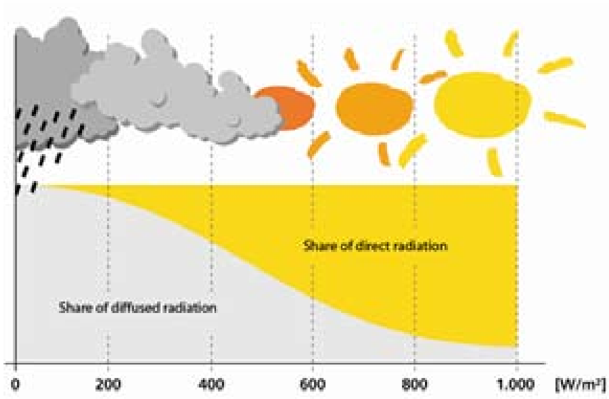


Fig. 17: Shares of direct and diffused radiation

In principle the overshadowing of the solar installations cause losses of insolation and output, and that is why they should be avoided. In solar installation, integrated in the building, there are typical cases of overshadowing which can be caused by parts of other building such as bay-windows, chimneys, aerials, as well as neighboring buildings.

The influence of trees and other vegetation in the neighborhood is often underestimated and their growth is not taken into account. Such overshadowing cause reduced and non homogenic intensity insolation on solar installations and lead to energy loss. That is why during the designing stage one should choose a situation without overshadowing for the solar installation.

Installation Conceptions

Several diagrams of solar installations for an overview of the possible conceptions follow.

Installation with two water tanks

Fig.18 shows the water tanks, connected consecutively. This system is implemented in a case when the necessary storage volume cannot be achieved by installing only one water tank or when an already existing solar installation is expanded. In this conception the tendency is the hotter water tank 1(the preferential one) to be charged always when the radiation is strong enough.

When the radiation is limited the colder water tank 2 is charged; at increasing radiation the collector temperature cannot be raised to the level of the preferential water tank.

Here apart from the temperature probes an additional radiation probe, giving information about the actual radiation intensity, is necessary. In case of increasing intensity the probe switches on the water tank 1.

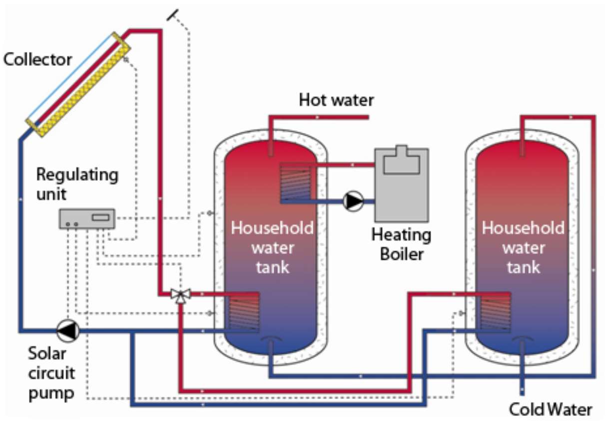


Fig. 18: Connection diagram of an installation with two tanks

Installation with a buffer tank

The structure and functioning of this type of installation correspond to these of the standard installations. The heating water, whose desired temperature is maintained by a solar installation or backup heating, is contained in the buffer-storage tank. The heat losses are reduced due to the principle of work with one water tank and the solar installation efficiency is much higher. An important advantage is the safety in relation to the legionellae. Because of the flow principle of warming the heat exchanger has to be calculated with particular attention in this type of installations. The heat exchanger intensity has to be coordinated with the peak consumption of hot water. This means that the peak load has to be determined accurately in advance. The heating circuit is fed directly through the buffer-storage tank. The backup heating requires

a little bigger cost for the regulation since a three-way valve has to be regulated so that the household water and heating of premises fills the upper, respectively the middle section of the buffer-storage tank, depending on the heat need. The solar regulation functions as in a standard installation.

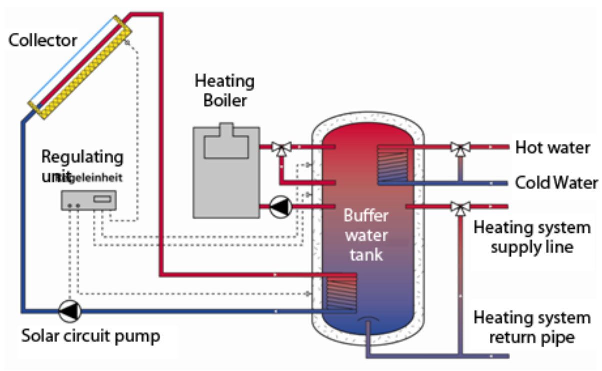


Fig. 19: Connection diagram of an installation with a buffer tank

Inclusion in existing installations

There is a considerable market segment for solar installations in the sphere of updating of older one-and-two family houses. In these houses there are heating boilers with acceptable annual efficiency, but at a lot of places updating is necessary since according to the Energy Saving Regulations (EnEV) 2 million heating boilers have to be replaced till the end of 2006. In these cases back up solar installation can considerably improve the situation. In each case the designing according the needs and the execution require a detailed picture of the installation sections and an accurate specification of the client's requests. There are usually no problems in the hydraulic connection of the backup heating. It can be implemented by a three-way valve or a regulated charging pump. Special attention should be paid to the regulation because hardly any standard solutions exist.

There are several solar regulating devices for backup heating on the market but in each case it has to be compatible with the regulation of the heating installation and must not, for ex., switch of the safety devices of the heating boiler. In this case the point is that the supporting water tank is replaced by a two-valency solar water tank. The existent charging pump and the regulation are used.

The existent temperature probe should be also used since it fits to the existent regulation system. If necessary the probe cable should be elongated or one should supply a new probe from the boiler manufacturer. The same should be done if a three-way valve is included in the heating circuit instead of a charging pump. The case is more complicated when the solar regulator has to take the function of backup heating. For this purpose the solar regulator has to communicate with the heating regulator for activating the preferential hot water switching on. Only in this way the cooling of the heating supply pipe during the time of the backup heating is avoided and, respectively, the meaningless lengthening of the backup warming stage. The use of integrated or added water tanks to the heating installation is advisable only in some cases. As a rule this variant is an undesirable way of connection because of the following reasons:

- The water tank, integrated in the heating boiler, shows considerably bigger heat losses in comparison with the solar water tank and does not allow temperature demixing.
- Possible idle times, weeks or months long, cause hygienic problems.
- The additional elements and time for installing increase the cost for the solar installation without increasing the output (economic efficiency!).

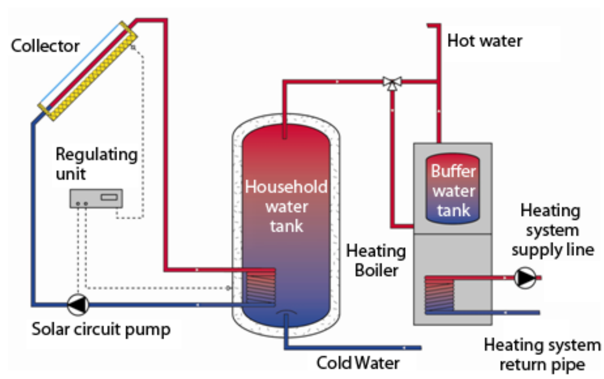


Fig. 20: Connection diagram of an installation to existing units

In conclusion we recommend once again not using electrical heater hastily because this can lead to fatal consequences for the installation efficiency and the climate preservation.

Backup heating

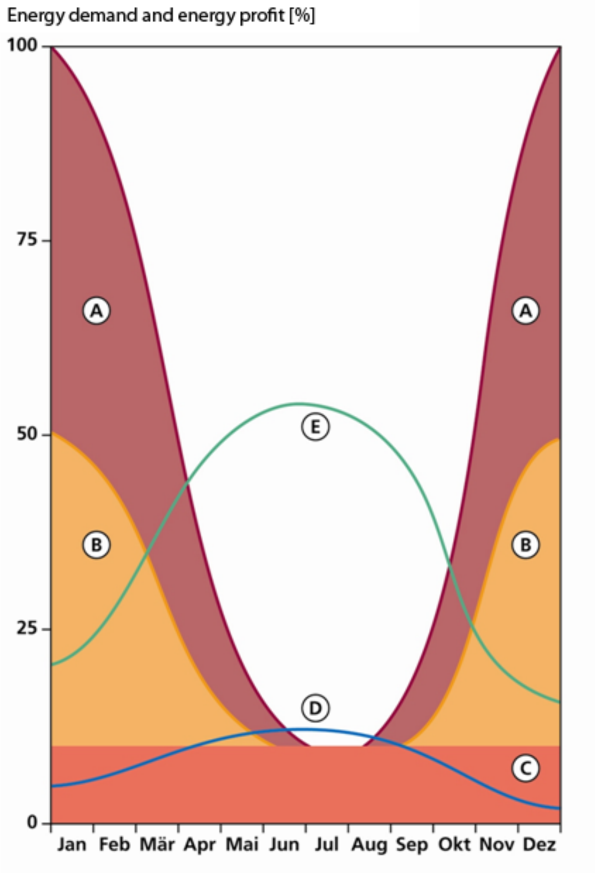
About one/third of the energy, used in Germany, goes for building heating. The energy consumption for premises heating in most of the buildings is bigger than that for hot water production. Consequently, the field of the building heating offers big potential for solar installation implementation.

A necessary condition for solar backup heating is the structural heat insulation according to the standard for a low energy house. The use of solar energy for building heating is complicated by the solar radiation which is seasonally opposite and the heating energy demand, while the need for hot water is almost constant throughout the year.

According to fig.21 the backup heating installations have to possess a comparatively big collector area for supplying a bigger covering share. Generally the energy, produced by the sun, can cover the entire energy amount for the heating of a low-energy house if the energy, produced in summer, is used in winter owing to a long-term water tank. Such conceptions about seasonal storage are suitable only for residential areas with more than 100 building units and for now are implemented by water tank with big volume, dug in the ground. The pilot installations, put into practice in Germany, can cover about 50% from the total heat needs (heating and hot water) of one residential area. The backup heating requires a buffer tank and a hot water tank.

For the right functioning of the combined water-tank conception it is necessary to maintain temperature demixing when filling and emptying. By the way this technique requires prevalence of a suitable volume flow rates in the primary and the secondary circuits and avoiding the recirculation of the water tank content. The cold lower layers of the water tank have to be fed to the leading out collector pipe in order to avoid efficiency losses.

For the optimal use of the layer charging technique it is advisable to use the Low-flow conception. In this way the passing through the solar circuit is reduced to 10-15l/ (m2.h): in the conventional systems the passing flow is about from 30l/ (m2.h) to 50l/ (m2.h). Because of the bigger temperature range solar installations with Low-Flow passing reach considerably higher temperatures in the supply pipe reaching and even exceeding the set up hot water temperature.



A Amount of heat needed in a family house (built after 1984).
B Amount of heat needed in a low-energy house
C Amount of hot water needed
D Solar energy output of a collector its area being 6 sq m
E Solar energy output of a collector its area being 25 sq m

Fig. 21: Heating needs and energy production from solar installations for hot water and heating

Special Applications

Compact installations for water heating

Along with the solar technical installations, discussed in the previous chapters, there are unit-type installations which are installed as a unit on the roof. They serve for water heating and are the most often used in south countries. Both basic structural forms are:

- Integrated collector-accumulator installations (IKS-installations), or, for short, accumulating collectors
- Thermosiphon installations

Accumulating collectors

The IKS-installations represent the simplest type of thermal solar installations. They are also called accumulating collectors because the collector and the tank represent one unit, i.e. the hot water is heated and stored directly in the collector. Since the water remains in the collector at night as well as in bad weather, the requirements for the frontal heat insulation are high. It can be made as transparent heat insulation (TWD) from polycarbonate material of “honeycomb” type. The additional heating can be carried out by an electrical tube heater or by an inflow one, additionally turned on.

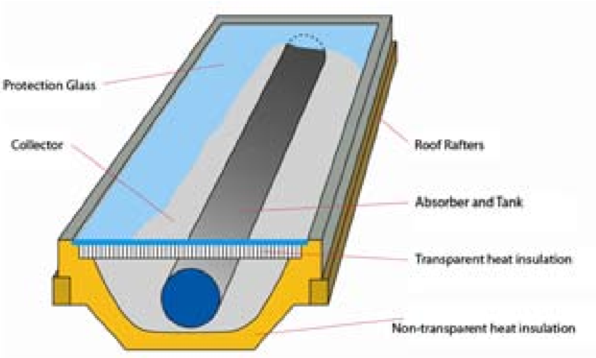


Fig. 22: Cross section of an accumulating collector

Advantages:
- Easy erection of the installation, there is no tube circulation circle between the collector and the tank
- Low installation and erection costs
- Minimum maintenance

Drawbacks:
- Difficult integration with the household electric appliances, in most cases considerable length of the cold water linking pipes, the heating installation and the distribution system for hot water in the basement
- Increased heat losses and less intensity compared with the conventional solar installations
- No freezing protection (links!)
- Possibility for overheating and limestone precipitation

Thermosiphon Installations

Here the circulation is carried out without support energy between the collector and the tank according to the so-called thermosiphon principle (principle of gravity). The heat transfer liquid is heated in the collector. The hot liquid in the collector is lighter than the cold liquid in the tank and because of these density differences a circulation begins, caused by the gravity intensity. In the tank the heated liquid gives its heat to the household water and falls again to the lowers point in the collector circle. That is why in the thermosiphon installations the tank has to be above the collector.

In the single-circuit installations the household water circulates directly in the collector circuit. In the double-circuit installation the heat transfer element in the collector circuit and the household water are separated by a heat transfer component. Thermosiphon installations are offered as units, installed on a frame in advance, or are integrated in the roof. An additional heating can be carried out by an electrical tube heater, respectively heat transfer component or an inflow heater, turned on additionally.

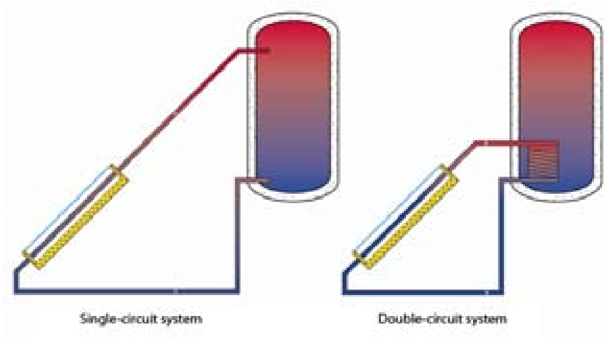


Fig. 23: Systems using circulation by gravity

Advantages:
- The pump and circulation regulation are not needed as well as the additional energy necessary for them
- Easier erection of the installation
- Lower installation and erection costs
- Minimum maintenance

Drawbacks:
- Difficult integration with the household electric appliances, in most cases considerable length of the cold water linking pipes, the heating installation and the distribution system for hot water in the basement
- There is no freezing protection in a tank for household water situated outside.
- Problems with mixing in tanks, situated horizontally

Air-collector installations

In Germany flat-plate collectors (air collectors), cooled by air, are rarely used since hot air installations are hardly in use in residential buildings. In bigger buildings (schools, administrative buildings, hospitals) the mechanic and supply of removal air by ventilation systems has been established since a long time. This is an interesting field of implementation for the air- collector solar installations because of two factors. On the one hand because of the present ventilation systems and on the other - because of the heating necessity mainly during the day.

For improving the heat transfer between the absorber and the air flow different forms of air collectors are used: ribbed absorbers as well as porosity absorber structures.

Advantages:
- No corrosion or freezing problems
- No problems, caused by non-sealing

Drawbacks:
- Comparatively big energy consumption for making the air flow move
- Difficult heat regulation and storage

Combining solar thermal installations with other renewable energies

Solar thermal installations are an advisable complement to wood-pellet burning installation. Particularly during the summer months the wood-pellet burning cookers and heating boilers are replaced by them. A STI saves fuel according to its parameters. A solar installation for backup heating of premises contributes to the climate and resource preservation even if combined with oil or gas heating. In these cases financial savings depend on fuel cost saving as well as on additional costs for erection, operation and maintenance of the solar installation.

The combining of the solar installation with wood-pellet fired boiler also leads to fuel saving (wood pellets). This does not lead directly to a considerable positive ecological effect as it doest in oil or gas heating. The result is that the renewable, but potentially limited wood will be available to more consumers than in the case of heating without solar installation. The advantage of the combining a solar installation with a wood-pellet fired boiler consists in the fact that during the summer months the wood-pellet heating can be turned off and thus the frequent turning-on and off is avoided. On the other hand, in this way the loading of the wood-pellet heating is reduced which could influence unfavorably the economic efficiency.

The heating installations usually have a heating circulation circuit which feeds the radiators and a circulation circuit for drinking water which heats and supplies drinking water. If a solar installation is included, a third circulation circuit - a solar one, will be needed. Meanwhile different manufacturers offer different conceptions for combinations of heating boilers or fireplaces with water jackets, burning pellets, with a thermal solar installation through a heat-storage tank. The solar circuit, full of non-freezing heat transfer fluid, has to be separated by a heat exchanger from the circulation circuit for heating or drinking water, which can be done by different installation conceptions. There is some difference between the solar installation for warming up of drinking water or for backup heating of premises.

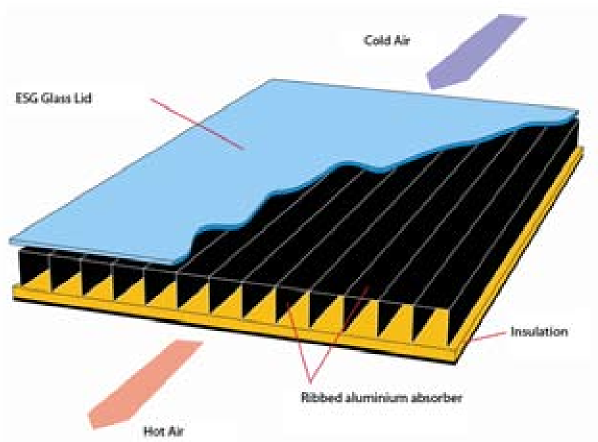


Fig. 24: Air collector principle

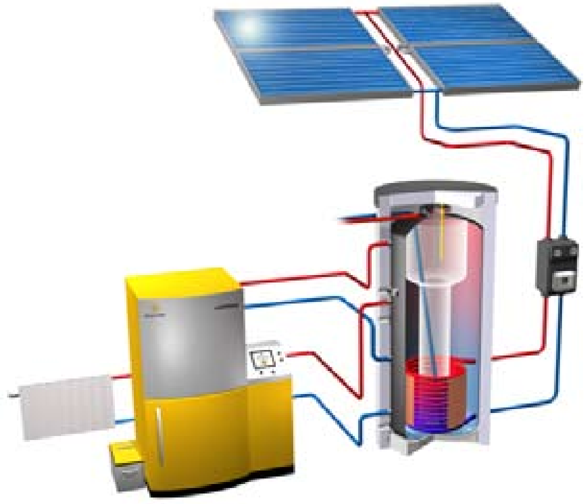


Fig. 25: Example: a combination between a wood-pellet fired boiler and a solar installation (Source: Wagner & Co

Economic Efficiency Evaluation

In the economic efficiency evaluation different investment models are compared in order to establish the most profitable one. At the present costs of the fossil and nuclear energy carriers this could be the solar installation but only under favorable conditions. The conventional ways of the economic efficiency evaluation have some weak points which have to be taken into account in respect with the installations with renewable energies:

- When supplying fossil energy carriers one does not take into account the damages to the environment and the health
- The reserves of oil, gas, coal and uranium keep decreasing, at the same time the energy consumption is increasing - the cost development cannot be foreseen, but it is increasing.
- The access to fossil energy carriers (conflicts, wars) which is wrongly regarded as cheap is paid off by all citizens.
- The risks of the nuclear energy (intermediate and final storage) are not taken into consideration.
- The fossil and the nuclear energy production are subsidized by tax money, amounting to billions.

The costs will be discussed below. The specific costs for a kilowatt hour heat, produced by the sun, are calculated for the solar system costs taking into account the energy output and are designated as price of the solar heat. For making the comparison of the costs possible they are calculated according to the annuity method. The annuity is a periodically permanent sum, consisting of the interest share and the paying off of the invested capital.

The repayment is subdivided into two categories according to their time planning: lump-sum and running payment. For the time period discussed the duration of use of the short-term and/or capital, requiring components of the investment, is essential. The remaining value of the fixed capital formation has to be calculated for the rest of the components. The solar installation is usually regarded as a whole and after the end of the evaluation period it is considered as amortized and a remaining value is not included in the calculation. The following costs should be taken into account:

- Capital related: interests, paying off and maintenance costs
- Consumption related: for back up energy
- Production related: in a solar installation, for ex. insurance costs

Capital related costs

The capital related costs are the main ones in solar installations. They consist of the invested sum, reduced by public stimulation means and, partially, by repair payments. In calculating the costs for repair and maintenance the relative coefficient has to be lower than in the conventional heat-producing installations since the amortization of the solar installations is comparatively more limited. As a rule the bigger the installation is the lower the coefficient is. The type and the scope of the maintenance activities are of particular importance-these are visual inspections during which the staff come and go. Besides that the share of the investment costs for different parts such as pumps, valves and expansion vessels considerably increases along with the increase of the installation size.

Consumption related costs

In the solar installations these costs are made for back up energy, mostly for electrical energy for the regulation and the pumps. In principle between 2% and 5% of the solar output is planned for the above mentioned costs.

Production related costs

Unlike the conventional installations for energy production the solar installation do not need service staff. Instead of them costs for the solar installation insurance are calculated. Depending on the insurance type the costs are different (building insurance and solar insurance). The building insurance is increased according to the building size, and the solar insurance - according to the solar installation investment. In most cases solar installations have not been insured up to now.

Description of Typical Cases

Examples for the implementation of solar thermal installations in the agriculture in the Hanover region have not been found out or have been insignificant. Two examples from Hanover are going to be discussed instead.

Solar city Kronsberg

In the framework of the Ecological Optimization Kronsberg EXPO-project the main regional city Hanover set out the objective to reduce the CO_2 emissions by 60% by the Energy Optimization Project. For supporting this objective innovative construction entrepreneurs were stimulated to implement the respective pilot projects. In 1996 the city of Hanover received stimulation funds from the European Commission in the framework of the THERMIE program. The Solar city, one of the subsidized projects, is going to be discussed here.

The Solar city residential installation is a pilot and demonstration project of the City Association for Building Construction GBH, the Avacon Energy Supply Enterprise and the Energy Agency of Lower Saxony. Solar city is a visual illustration that the construction of social dwellings for renting is suitable for solar supply.

A total of 1.350 sq.m. of solar collectors replacing the conventional roofing are integrated into roof surfaces facing south and supply heat to a total of 104 dwellings. By means of a well insulated, long-term-heat-storage tank with a volume of 2.750 m3, the solar energy can be used from the spring to the mid-December. In this way about 40% from the total consumption of heating energy are covered and the use of fossil fuels is considerably reduced. The rest of the necessary amount is supplied by the heating station, situated in the neighborhood through the existing heat supply network. The heat-storage tank, mentioned above, consists of new type dense concrete with increased supporting capacity, having a supporting and sealing function which makes redundant the inner coating of stainless steel.

The optimized cylindrical form of the tank and the insolation of penoglass granulate, resistant to humidity, considerably reduce the heat losses. The tank, situated on a surface of 530m2, is dug in the ground at 6-m depth and is stuck out as a flat rising ground of 4.50m over the surface. While on the other sides the tank is covered with soil and integrated in the landscape, a concrete wall, shaped as a climbing wall, faces the housing complex and is included in the playground of the neighboring kindergarten.

The total costs amount to 3.3 million Euro from which 52% are for the solar collectors and 48% for the heat-storage tank. Along with the money from the special EU-THERMIE project of Hanover grants from the Federal Ministry of Economics, Technologies and Transport, the Kronsberg Agency for the Environment and Communication, the Grosraum Municipality Union-Hanover and the Concrete Marketing were received. 65% from the total sum were collected by stimulation funds.

Karl Lemerman House

The Karl Lemerman House, built in 1958, is a residential building for homeless men. In 2002 the building was updated energetically on a large scale by erecting a solar thermal installation. Two principles were crucial for its erection. On the one hand the production costs' reduction and on the other - the financial investors union participation in the framework of the pedagogical project "The sun as a sign of hope."

The building has medium to high insolation standard and the solar installation serves mainly for heating of household water. Moreover the heat energy consumption was reduced by more than 5%. 33.000 Euro were invested in the solar installation with a 40 sq m collector area. 50% of them were granted by the province of Lower Saxony.

Along with the thermal solar installation a photovoltaic installation (4.7 kWp) and an installation for rain water use were installed. Other examples of big thermal installations are published on www.solarge.org.

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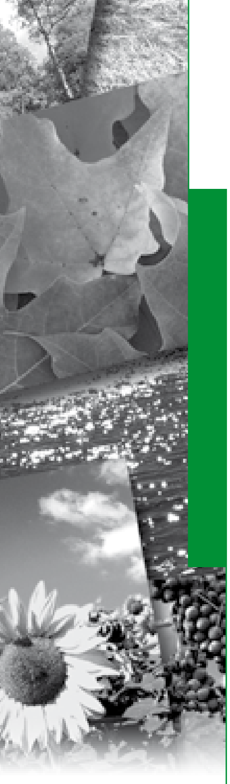


PHOTOVOLTAIC SYSTEMS

Introduction

Solar Photovoltaics in Europe

The last years saw a considerable increase in the share of solar photovoltaics in the total electricity generation in many European countries. This is due mainly to the energy policy pursued, which discovered renewable energy not just as an effective instrument to reduce green house gas emissions but also a possibility to develop new production. This has resulted in favourable consequences for the economy and population as well as environment by reducing the areas for industrial purposes.

The Kyoto Protocol is of enormous importance as it not only commits countries to adopt measures for the reduction of green house gas emissions but also aims at making a strategic change in economic and industrial policy including innovative methods of development. The new energy strategies related to renewable sources can make a notable contribution to this end. The world photovoltaic market is very young with substantial growth during the last decade.

The White Paper envisages a substantial growth in the field of renewable sources – the existing 16 MW in 1997 are to reach 300 MW in 2010. During the last 20 years photovoltaic market growth trend has been even more substantial. Photovoltaic industry production features a 10-times increase every 10 years. The global production of photovoltaic cells was 1256 MW for year 2004 (too big compared to the previous year with its 750 MW). Currently the growth process covers both big production capacity and installed capacity. More and more new companies become part of the photovoltaic panorama, especially in the field of photovoltaic modules. Using photovoltaics big companies having their main operations in the petrol industry (Shell, BP), the production of semiconductors and consumer electronics (Sharp, Kyocera) as well as 100% (pure) photovoltaic industry (Photowatt, Isofoton, Astropower), managed to occupy an important market niche. There is a great production concentration: renewable-energy oriented Japanese electronics and petrol companies account for three quarters of the world production of photovoltaic cells. As far as demand goes, 2004 saw a real boom of photovoltaics in the German market, to a great extent due to energy-related incentives applied. That has turned it into a historical year for photovoltaic industry development because of the new installed units amounting to 303 MW (about 3000 new installations), a turnover of 1.350 million Euro and 18.000 working places in this sector. The main obstacle for the development of photovoltaic production used to be the scarce legislative and regulatory framework in the different countries. Nowadays difficult as it is, specific legislative measures are undertaken, although not always adequate ones. The other impediment is mainly economic. In order to achieve a real large-scale market penetration, photovoltaic production is to drastically reduce investment costs, i.e. to considerably cut down the expenses for materials and for cell production. As far as non-photovoltaic components of an installation are concerned - inverters, supporting mechanical structures, etc., great technological innovations cannot be made: considerable reduction can be achieved by large-scale savings related to an increase in production facilities. However, the situation with modules is quite different: costs reduction seems possible only by using innovative technologies, related to both materials and production processes. The latter in particular are to be developed towards full automation, even when this contradicts the requirements for "top quality", applied in the production of hi-tech components where high quality is of extreme importance. Further expansion of the photovoltaics market requires not just making efforts to considerably improve production processes but also stimulate demand economically through incentives and financing while placing special emphasis on distributive generation. Distributed generation (DG) means the use of a great number of small- and medium-capacity generating systems, connected to a distribution utility grid for the power supply of an individual customer or for the maintenance of that grid. DG comprises generating systems connected to a distribution utility grid as well as energy accumulation and control systems, which are to meet energy demands along with big distribution plants. The spread of such systems can be affected positively by various factors. The early 80ies saw partial however decisive turnaround to large-scale savings in electricity generation, resulting in the installation of facilities with a capacity of about 1.000 MW. Nowadays the optimum demand for some technologies and applications is about several tenth of megawatts. Therefore, building small and medium-capacity electrical plants is economically feasible. As far as technologies are concerned, power industry orientation turns to smaller and smaller generation units. Future scenario envisages reassessment of centralized generation in favor of distributed generation, implemented through a number of small and very small plants for micro generation, which are quite suitable to meet the energy demand of civil structures – residential dwellings, hospitals, hotels, supermarkets, molls. Each individual family using a small autonomous installation is a proof that each citizen can be an independent producer thus increasing the benefits of this type of generation:

- a possibility for structuring of local energy resources;
- smaller or no necessity for transportation due to the proximity of generation and consumption;
- greater spread of power generation;
- reducing dependency on energy import;
- as a domestic source of electricity, it contributes to the nation's energy supply security.

The table below is an overview of the cumulative installed capacity in some European countries by 2004:

Country	Total Installed Power by the end of 2004 in kW
Germany	794.000
The Netherlands	47.000
Spain	38.696
Italy	30.300
Luxembourg	26.000
France	20.119
Austria	19.833
United Kingdom	7.803
Greece	4.544
Sweden	4.140
Finland	3.702
Portugal	2.275
Denmark	2.245
Belgium	1.460

Source: EUOBSERVER

European strategies for the development of Solar Photovoltaics

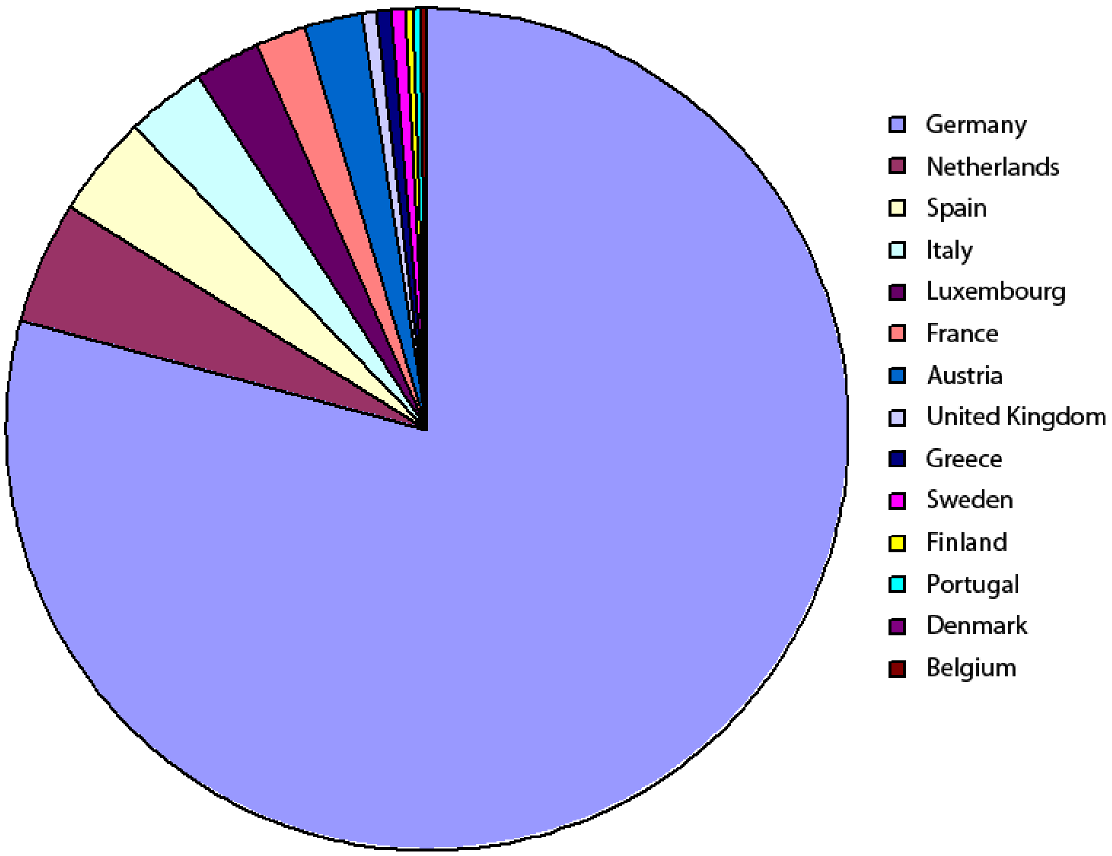
Europe played a key and leading role worldwide in the discussion held to support the Kyoto Protocol. After USA resignation in June 2001, Europe undertook unilateral ratification of the Protocol with a commitment, signed by all European Union ministers of environment. On February 6th 2002 the European parliament voted a resolution for the ratification of the Protocol – ratification, which remains an obligation of the individual member states. The European Union has demonstrated its commitment concerning environmental problems, resulting from the use of conventional energy sources, defining its guidelines and objectives as well as determined the contribution of renewable energy sources to gross inland energy consumption in the EU during the following years. In the White Paper the Commission has set a global indicative objective of 12% contribution of renewable energy sources to gross inland energy consumption in the EU in 2010 equivalent to 182 Mtep of the total projected 1.583 Mtep. Currently the relative share of renewable sources is less than 6%, equivalent to 74,3 Mtep of the total inland consumption of 1.366 Mtep. In fact this means a 2,5-times increase of current renewable energy sources generation. In March 2000 the Commission published the European Climate Change Programme (ECCP). This programme underlines the need for greater efforts for the EU to implement the Kyoto Protocol targets of 8% greenhouse gas emissions reduction. ECCP report outlines a series of actions and measures which are to comprise a part of EU strategy.

An important element of the programme is the incorporation of existing initiatives which require further development to create consistent and compatible programmes (an agreement with car manufacturers for the reduction of CO2 emissions, directives on renewables promotion, an action plan for the promotion of energy efficiency, green paper for power supply, etc.). The measures outlined in the ECCP have been elaborated in the context of such existing initiatives. The latest data show that by 2010 the actions and measures undertaken are to reduce emissions by 1,4% maximum - below the 1990 level, in spite of the existing tendency of about 7% increase. Hence new steps are to be undertaken aiming at reducing emissions with 6,6% more. However, taking into consideration various difficulties and uncertainty in their implementation, new actions are assumed to be envisaged aiming at further 9% emission reduction.

The programme envisages interference in the following sectors:

- Flexibility mechanisms (as provided for in the Kyoto Protocol)
- Energy generation
- Energy consumption
- Energy efficiency at end consumers and industrial processes
- Transport
- Industry
- R & D
- Agriculture.

Cumulative Installed Power in Europe (kW)



Source: EUOBSERVER

The European Climate Change Programme discusses different strategies and already accepted directives, amongst which are the ones given below. The Green Paper "To an European strategy for power supply security" dated November 2000 showed clearly that the energy issue was not just of ecological or economic but of political importance as well.

In particular, a debate took place on the security of energy supplies, provoked by the finding that European energy dependence kept increasing. The European Union's dependence on energy imports is great. Currently EU's dependence on energy import is 50% and in case these tendencies continue, it is expected to reach 70% in 2030, with considerable dependence on hydrocarbons. Supply security is not targeted at achieving energy autonomy or minimizing the dependence, but at mitigation of the risks related to such dependence. Hence, expansion of the types of energy supply sources requires consideration (in products and geographic zones). Based on a preliminary assessment of some of the costs and benefits, the European Commission paper underlines the positive outcome of such actions on both environment and economy:

- The net investment has been estimated at 95 billion Euro (calculated by taking the total investment and subtracting the investment that would have been needed if the energy from renewables was provided by using conventional fossil fuel technologies)
- CO_2 emission reduction has been estimated at 402 million tons annually compared to 1997
- Increase of employment related to renewable sources sector has been estimated at 500.000 jobs for 2010. This is a net figure allowing for losses of jobs in other competitive sectors.
- Potential growth of the European renewable energy industry in international markets can add to the European trade balance about 17 billion Euro annually from import activities.

Prospects for use in rural areas

Starting from the Rio Climate Change Conference in 1990, through the Kyoto Conference in November 1997 and at the end the World conference for sustainable growth held in Johannesburg in 2002, a system of common guidelines was drawn up to solve the problems related to development. Gradually the common conviction has been confirmed, that the development of solar and wind energy technologies as well as their distribution are our priority objective, provided such installations do not disturb the landscape and the existing habitat and be implemented in the best possible way. A lot of territories have specific characteristics used by the EU to define rural areas. Today we have realized that undeveloped, deserted and agricultural territories offer an absolute possibility for such lands often called "unattractive" to become areas of growth, combining their peculiarities with the new technologies thus stimulating the economic development of these regions.

Besides evaluating these regions in terms of agriculture, nature and tourism, currently actions can be undertaken to stimulate the protection of environment by meeting energy demand using renewable sources and at the same time providing income from the economic activities typical for these territories. In most of these rural areas except for natural resources there is also a unique, reliable and predictable source – the sun. This source is not just abundant and constant but can also be calculated in average annual values. This enables the parameters and advantages of its use to be calculated in advance. The use of photovoltaic installations in European rural areas should become a laboratory for experimenting with production technologies and processes in different agricultural sectors; this is to become a place to implement pilot projects, to test and assess production, genetic fauna and flora species, etc.; a place which will be a type of educational centre of European citizens for courses, lectures and training, dedicated to integrated rural development, environmental economics, etc. In this context renewable sources and photovolaic facilities in particular can play the main role, being fully integrated into the energy development of rural areas.

Environmental impact

Photovoltaic systems have extremely lower environmental impact. A photovoltaic installation generates electricity and it enables its saving, but at the same time its constructing, transporting and dismantling at the end of its service life require a certain amount of energy. Hence it's very important that the emissions, avoided in the application of a photovoltaic system during its operation compensate the emissions, generated during the stage of photovoltaic modules production for a period shorter that its operation time. Today this "Energy Pay-back Time" (EPBT) can be defined as the time which is necessary for the energy saved due to the photovoltaic installation to be equal to the demand during the whole service cycle. The energy pay-back time values are evidenced for about 3 or 4 years. This period of time is much less than the expected operation time of an installation (over 30 years). Therefore, taking into consideration the entire operation cycle of a photovoltaic system, it has net benefits for the environment. The only considerable impact on the environment is the occupation of a larger area as far as power plants are concerned as well as periodic replacement of storage batteries in stand-alone systems. As for the latter, it's obvious that environmental problems can be limited by organizing careful collection and adequate recycling. Of course this does not mean that photovoltaic installations of any size can be installed anywhere. In some cases serious problems can arise with regard to spoiling the beauty of the landscape or occupying an area. These are impossible to be ignored in the design, taking into consideration the environmental factor. Even though photovoltaic energy generation can require larger areas due to the diffuse nature of sun light, the possibilities to reduce environmental impact are quite different depending on installation size and type. With smaller installations it's comparatively easier to use systems enabling better integration with the existing architectural and landscape characteristics. Today great attention is paid also to the aesthetic aspect of photovoltaic technology – modules are to be compatible with the other roof building materials. Aesthetic aspect importance is supported by the availability on the market of modules and shapes different from the standard ones or with special colours and design as well as the availability of real photovoltaic roof tiles, sometimes even flexible one, to be used instead of the conventional ones.

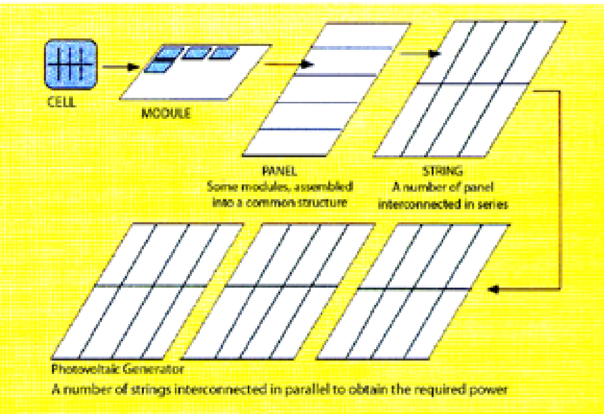
Unlike the other renewable energy systems, which can be installed just in locations with abundant resources (such as water or wind power facilities), photovoltaic installations can be located anywhere. Hence, even aspects that are closely related to the landscape should be considered in this case.

Technological aspects of Solar Photovoltaics

Photovoltaic roofs: Installation types

A photovoltaic cell is the main component of a photovoltaic installation which converts sunlight into electricity. It consists of a thin plate of semiconductor material, typically silicon, with a thickness that varies from 250 to 350 microns and an area of about 100 cm2 (to 225), functioning like a small battery. For cells to function, photons which comprise sunlight are to have higher energy than a specified minimum value, and this depends on the material of the cell. When a photon having sufficient energy is absorbed by a cell, a pair of opposite electrical charges is created in the semiconductor material which it is made of: an "electron" (negative charge) and an "electron hole" (positive charge). In this case we say that these charges are available for electricity generation. However, to effectively generate electrical current, there should be an electric field in the crystal itself to orient electron movement in the desired direction. A constant internal field can be obtained by adding small amounts of admixtures into the material which cells have been of. Such admixtures, called "spices" can change the electrical properties of a semiconductor to a great extent. In case semiconductor material is silicon, adding phosphorus atoms will make a "n"-type silicon, which features a higher density of its free electrons than of the one of standard silicon. However adding boron atoms to silicon will result in the formation of a "p" silicon, in which the redundant charges are positive. Photovoltaic cells require a close contact between the two silicon layers ("p" and "n") over a large area. High electric field is generated in the contact area of the two types of silicon, called "p-n" junction. The electric field directs sunlight generated electrons to the "n" layer, and electron holes – to the "p" layer. Connecting both layers by an external loop results in the circulation/flow of electrons, i.e. direct electrical current between "n" and "p". The more the amount of sunlight, the more the current generated. The maximum theoretical efficiency of converting sunlight into electricity is 32%. Photovoltaic cells in the market have a lower efficiency - within 10-15%. The semiconductor material that is generally used today for the production of photovoltaic cells is silicon. It is used in various forms: single-crystal, polycrystalline and amorphous. Nowadays the first two types of silicon are wide spread in the market. Partially single-crystal and polycrystalline silicon are manufactured by processing waste material from electronics industry (semiconductors), where the requirements to material purity are quite high. In photovoltaic technology these requirements are much lower. Silicon is wide spread due to its reliability. Typically its colour is blue but it can be produced in other colours as well – in the yellow, green and red range of colours. Quite interesting is the latest technology for the production of photovoltaic cells, called "thin film": these are some industrial products supplied in "sheets" having a thickness of some tenths of the millimetre. Some of them are very light and flexible, which makes them suitable for non-standard installation conditions (for example, uneven surfaces) as well as for installation onto cars and boats, for power supply of specific equipment (radiophones, charging of batteries, etc.). Solar cells are an intermediate product of photovoltaic industry: they provide limited amount of voltage and current compared to the ones required typically by the units powered, they are very fragile, without electrical insulation and mechanical support. That's why they are installed in such a way that they make a complex structure, the so called "photovoltaic module" – a "sandwich", comprising materials with good conducting and resistant characteristics and middle part which is cell's surface.

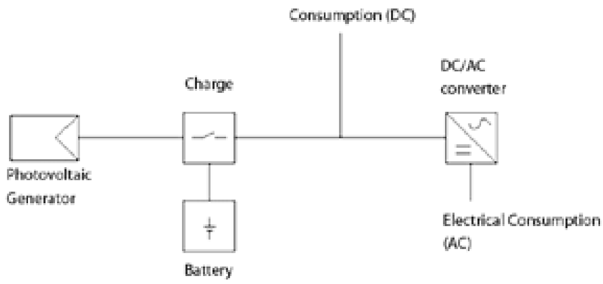
Modules are the major component of all types of photovoltaic systems. They are integrated into a structure called panel. When modules are interconnected in series, the total current becomes equal to the one of the module, generating the smallest amount of current, the total voltage being the sum of the voltages of the individual modules. A number of modules interconnected in series make a "string". A number of strings interconnected in parallel make the so called "Photovoltaic generator":



Inside modules the cells are encapsulated between two protection layers, which can be made of glass (glass-glass modules) or transparent plastic resins (transparent plastics-transparent plastics modules). Combinations exist with glass as upper/front layer and transparent plastics as backing layer (glass-transparent plastics modules) as well as flexible or folding modules made of amorphous or thin-film microcells. Fixed modules are usually supplied with an aluminium frame round the circumference, carrying the devices for hanging and fixing to supporting structure onto which modules are to be installed. A distribution/junction box with electric connections is located at the back of the panel. Photovoltaic installations can be grouped in two big categories:

- Isolated (Stand-alone) systems
- Grid-connected systems. Refer to the following page for further information.

Isolated (Stand-alone) systems



Generally stand-alone installations are used to provide electricity to customers located in hard-to- access areas. As electricity consumption is limited, expenses for connection with the power grid are not justifiable. Photovoltaic installations generally offer more economic alternative for power supply at distances over 3 Km away from the existing electricity distribution grid.

Currently the following types of installations are most widely spread:

Flat passable roofs:

This type of roofs can be found most often in bigger residential areas mainly on reinforced concrete and/or steel-structure buildings as well as multi-storey (multifunctional systems) and single-storey (monofunctional systems) ones. Undoubtedly flat roofs are the most suitable ones for photovoltaic system installation as there are no restrictions to their orientation. Modules are installed onto individual support structures and the system can have optimum orientation to get the highest annual energy generation. However aesthetic appearance is not always good.

Sloped tile roofs:

Sloped roofs covered with tiles are typical for geographic areas with severe winter and frequent snowfalls. Modules are installed onto the sloped roofs of the buildings. The slope determines installation efficiency and energy generation may not be optimum. However, on the other hand support structures may not be required. Hence aesthetic appearance will be better due to better harmony between the building and the installation.

Façade systems:

The facades of a building can provide large areas and potential for very aesthetic installations especially when combining photovoltaic systems with other components like glass surfaces. One of the disadvantages is the small amount of sunlight reaching façade surfaces compared to sloped ones in South European latitudes.

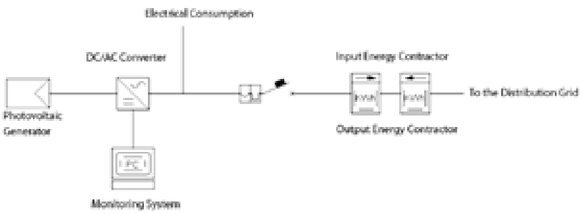
Building integrated installations have different advantages:

• they do not require special-purpose areas using surfaces that are unused anyway. That does not have additional impact on environment. New areas are not occupied, as is the case with power plants, where modules are installed on the ground and arrays should be at a given distance not to cast shade on each other. Such a module occupies an area about twice the useful surface, i.e. of the effective area covered with modules and required to convert sunlight into electricity.

• some of the materials used for supporting structures, which are typical for a power plant, can be avoided, using the supporting structures of the building on which the modules are installed. Moreover, part of the materials for covering a building can be replaced by photovoltaic cells, functioning in this case as a real roofing structure. Of course the savings mentioned above are obtained only when designing the photovoltaic system simultaneously with the building and cannot be achieved in case of modifications, i.e., when the interventions are made on the building already constructed.

• an integrated photovoltaic system is able not only to generate electricity but improve and optimize energy flows between a building and the environment as well.

Let's see the components and functioning of a small-size grid-connected photovoltaic installation:



The three major components are as follows:

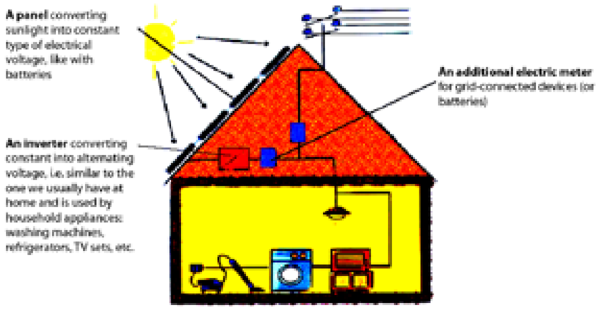
Photovoltaic modules – inverter – electric meter.

A **module** generates electricity by converting sunlight into constant type of electrical voltage, like with batteries.

An **inverter** converts constant into alternating voltage, i.e. similar to the one we usually have at home and is used by household appliances: washing machines, TV sets...

An additional **electric meter** for grid-connected facilities.

The constant-voltage electricity generated by photovoltaic modules connected in series is converted into alternating current by the inverter. AC is then fed to the power grid, supplying the electrical installation of the consumer. An additional electric meter registers the redundant energy (not used by the consumer) which is fed to the national electrical distribution grid.



An inverter converting constant into alternating voltage, i.e. similar to the one we usually have at home and is used by household appliances: washing machines, refrigerators, TV sets, etc.

Sizing and energy output

Photovoltaic cells are sized to meet fully or partially the electricity consumed by the consumer, for whom they are installed. With stand-alone systems, batteries are to meet 100% of consumer demand of electricity at any isolation status. With a grid-connected photovoltaic system, it can be sized to meet a different percentage of electricity consumption as well as generate more than the total electricity required, the redundant electricity being fed to the power grid.

The parameters that affect system sizing are quite many:

- electricity consumption (daily, monthly, annually). It's important to choose low electrical consumption devices, like special pumps and refrigerators, energy-saving lamps, etc.. Less energy demand results in using a smaller photovoltaic system and therefore, lower purchasing cost;
- time of use (daily, monthly, seasonally);
- available area. In case a big enough area is available, more adequate modules with lower converting efficiency can be used (however, requiring larger area);
- geographic location of the installation (latitude);
- sun light (daily duration, intensity);
- average ambient temperature.

To assist the sizing process, sun light during the day has to be assessed horizontally as well as the light which is caught effectively by the respective module surface with its angle and orientation. Shadow assessment can be made using a diagram of sun trajectories. It is of great importance for the system to be exposed to the sun during most of the daytime in the year.

Total consumption analysis goes through the following stages:

1. Assessment of the consumption of the available electrical appliances and an assessment of their maximum operating capacity.

2. Assessment of the possible interventions to reduce electrical consumption. Almost all interventions to save electricity and use highly efficent appliances result in cutting the costs for a photovoltaic system. The use of photovoltaics

is effective only when other consumption-reduction strategies are applied as well. According to this approach, the assessment of a widely used photovoltaic system (in a residential dwelling, tourist site, small enterprise) can be unbiased (fair) only when the possible electricity-saving measures have been accounted for as well.

3. Assessment of optimized electric consumption

Sizing of a grid-connected photovoltaic system is not of such a great importance as with stand-alone systems. The grid can meet consumer demand when there is no sunlight and electricity is required.

Conditions for installation functioning

Photovoltaic modules can be located onto any part of a building, owned by a consumer. The decision for the technical feasibility is determined by the place where they are to be installed as well as by the following factors, which should be inspected in situ by the designer or installation engineer.

- availability of the required area for module installation (useful area of about 8-10 m2 kWp of installed capacity is required);
- correct exposure and inclination of the area mentioned above. The optimum conditions for Italy are as follows:
- Southern exposure (Southeast and southwest are also acceptable with limited generation loss)
- 30-35° inclination;
- no obstacles for the sun light.

The main technical and architectural installation options are as follows:

Modified location above the roof

Incorporated in the roof

Onto a balcony

Incorporated into a vertical facade

Power grid connection

Differentiation can be made within the group of grid-connected systems between power plants and installations integrated in buildings. Power plants feature high capacity (from hundredth of kilowatts to several megawatts) and they are designed for centralized generation of electricity, which then is supplied to a national or local grid. These are plants for electricity generation and supply. Integrated installations have gained great popularity and importance recently, the possibility to be connected to the electrical distribution grid making them even more significant. They use building roofs and facades as the basic area for photovoltaic modules and aim at meeting the electricity demand of the customers, for whom they are installed (distributed generation). Therefore they have a relatively low capacity (from several kilowatts to tenths of kilowatts). Grid connection enables more flexible sizing. With stand-alone systems, photovoltaics and storage batteries are to ensure the whole annual consumption of a consumer. However, with a grid-connected photovoltaic systems, this is not necessary, because the power grid acts like a practically unlimited storage battery. This enables sizing to be made on the basis of other parameters, like the available effective area on a given roof or initial investment budget available. Integrated photovoltaic installations can be classified according to the location/arrangement of the modules on the roofing areas of a building.

Within grid-connected systems, building installations have various advantages compared with power plants:

- Integrated systems generate electricity exactly where it is required thus reducing considerably transmission losses, which can reach up to 7-10% in a single grid.
- The generation of electricity during sunlight hours enables decreasing demand from the grid during the day, this being the period of highest consumption. Assuming that photovoltaic system integration in newly constructed buildings develops on a large scale, we can envisage equalization of the daily peaks in electricity demand curves, corresponding to the most expensive energy generation. This is an interesting alternative, particularly taking into consideration the increasing use of air conditioning systems in residential and public buildings.
- Finally, the use of these systems is an incentive for the revival of better “energy awareness” with the customers, and this will have a positive effect nowadays with rationality and efficiency of energy use becoming more and more indispensable.

A customer being at the same time a generator and owner of an installation for electricity is going to use it more reasonably. Researches show a considerable decrease in the amount of electricity consumed in dwellings with photovoltaic installation.

Economic assessment

Installation costs

High initial investment costs are the main obstacle for the distribution of photovoltaic systems. However, maintenance and operating costs are limited, due to the simplicity and reliability of the devices used. Photovoltaic installation costs vary constantly, module price having decreased considerably with market expansion during the last decades. Today the average price of a photovoltaic module is about 3,5 - 4,5 Euro/Wp.

Nevertheless kWp installed price is still such that this technology is not competitive to the other energy systems without the application of promotional and incentive mechanisms. Costs are divided into two groups similar to the other sources: fixed costs – the initial investments required making an installation and variable costs – these are the costs to operate and maintain an installation. Generally variable costs include expenses for the personnel, fuel and spares, the “fuel” item being of course avoided in the case with photovoltaic system. Both investment costs and operating and maintenance costs depend a lot on the capacity of the installation, the type of application for which the latter has been made as well as the place where it will be installed. Currently the approximate price of a photovoltaic system is within 6.5- 7,8 Euro/Wp, but these values vary depending on installation size. The total cost for the installation of 2-3 kWp system for domestic purposes is from 14.000 to 21.000 Euro. The prices of photovoltaics evolve constantly. Considerable reduction can be expected depending on the amount of investments for research and development. The objective is to develop innovative technologies as regards materials and production processes, which can result in large scale production with great savings of energy, extension of system service life and higher cell efficiency, the latter being the determinant item in the general cost estimation.

Sale of energy to the grid: Energy account mechanism

The energy account is a mechanism to promote the generation of electricity by photovoltaic installations. European directive 2001/77CE on the promotion of electricity generated from renewables having been issued, a lot of European countries published ordinances on the criteria for directive application. Thus each country will be able to increase the amount of electricity generated by photovoltaic installations using a subsidy, which multiplies both economic and environmental benefits, and the manufacture of a photovoltaic installation becomes a real type of investment.

The functioning of this mechanism in Italy is examined in detail in Appendix 1. The main characteristics of some systems for the promotion of photovoltaic energy generation applied in five European countries are also given below.

The table shows different promotional tariffs depending on installation size and the duration of the respective promotional measure.

COUNTRY	PHOTOVOLTAIC INSTALLATION PROMOTISYSTEM
Italy	Electricity payment tariffs for 20 years: • 0,445 €/Kwh for an installation of up to 20 KW • 0,460 €/Kwh for an installation between 20Kw and 50 KW • 0,490 €/Kwh for installations of more than 50 KW
France	Electricity payment tariffs for 20 years: • 0,15 €/Kwh for an installation of up to 1 MW in Continental France • 0,30 €/Kwh in offshore departments and Corsica • VAT reduced to 5,5% for external installations on buildings
Germany	Electricity payment tariffs for 20 years with 5% tariff decrease from 2005 onward (6,5% decrease on existing installations from 2006 onward): • 0,46 €/Kwh minimum amount • on buildings and sonic barriers: 0,57 €/Kwh to 30 KW • 0,55 €/Kwh for installations over 30 Kw • 0,54 €/Kwh for installations over 100 Kw • for installations, integrated in facades, the tariff is increased by 0,05 €/Kwh
United Kingdom	Financing for installation manufacture and lower VAT.
Spain	The promotional tariff is equal to 575% of the reference KWh amount for 25 years • 0,42 €/Kwh for installations over 100 KW • 0,21 €/Kwh over 100 KW

Source: The European Commission – EUR 21242 "A VISION FOR PHOTOVOLTAIC TECHNOLOGY" (2004). Luxembourg: Office, Official publications of European Communities

Case studies

Agreement between “Legambiente” and “CBB” in Graceto province

Promotional financing for for renewable sources

Due to the increased interest in renewable energy sources, “Legambiente” and Cooperative Credit Banks (CCB) of Graceto province have decided to sign an agreement for extending a financial instrument, which is to facilitate installation construction. The agreement envisages that citizens, companies and public organizations taking interest in constructing installations, powered by renewable sources (solar-thermal, photovoltaic, wind and biomass) or high energy efficient ones, can use financing with lower interest rate (increased by 0.75 points above “Euribor” value) to 150.000,00 € maximum.

Having contacted an installation engineer or designer to prepare installation design and/or quotation, citizens can visit any of the offices of Cooperative Credit Banks, which have signed the above agreement and request a financing plan.

Following the requirements of the client, the bank shall prepare the plan and send an application to the National Centre for Promotion of Renewable Energy Sources to “Legambiente” for technical position regarding the installation to be financed.

Having reviewed the technical documentation, the Centre shall check whether it meets the requirements under the agreement and express a position which is mandatory for extending the financing. In case of a positive position, financing can be extended.

This financial instrument has two basic advantages:

Flexible and simplified procedures for promotional financing (about 3%).

It enables a customer to make investments, which despite of being repaid for 5 to 10 years (depending on installation type) do not require immediate payments.

In many cases loan instalments are paid by the savings made due to the new installation.

Using this financial instrument, installations powered by renewable sources are built with less expenses, environmental benefits being also higher.

FEASIBILITY REPORT ON THE CONSTRUCTION OF A SOLAR PHOTOVOLTAIC INSTALLATION FOR GENERATION OF ELECTRICITY NEAR AN AGROTOURIST SITE

The total annual consumption of electricity at the site is 23.000 KWh. The objective is to install a solar photovoltaic system having a capacity of 20KWp. It is envisaged for the panels to be installed on the roof of a cattle-shed that has long needed repair. The size of the selected installation has been determined on the basis of the average annual consumption of the site, i.e. the generated electricity will be just for consumption of the site. The installation occupies an area of about 200 M^2. If located on a flat roof or on the ground, it will occupy about twice the area mentioned above, because panel arrays are located at a given distance not to cast shade on each other. The installation is oriented to the south (efficiency is reduced slightly, if the angle does not exceed 45^0C in case of orientation to the east or to the west) and the inclination is 15-30^0C. Its generation capacity is over 1.200 kWh/annually for installed kWp (data, proven during the analysis of the operation of many systems installed in Toskana). An installation of 20 kWp has a generating capacity of about or over 25.000 kWh/annually and total cost of about 125.000 €. All the electricity generated by the photovoltaic system will be registered by a meter installed below. It will be paid to a promotional tariff - 0,445 €/kWh for 20 years (all the amount of electricity generated by the photovoltaic will be paid in this way), applying a “net-metering” mechanism, i.e. consumers will use the generated electricity according to their current demands and provide to the local power grid the excess amount of electricity, to be deducted in the receipts for their following bills.

The following table shows an estimation of installation cash flows for a period of 25 years.

The 25 years of photovoltaic module life guaranteed by the manufacturer having expired, the result with regard to

PERIOD YEARS	Generation kWh/y	Electricity saved €	Energy bill/account €	Profits € current
0				
1	0,00	0,00	0,00	0,00
2	25.493,17	3.380,00	11.726,86	15.424,10
3	25.289,22	3.515,20	11.633,04	15.791,15
4	25.085,28	3.655,81	11.539,23	16.172,57
5	24.881,33	3.783,99	11.445,41	16.549,54
6	24.677,39	3.903,10	11.351,60	16.925,14
7	24.473,44	4.025,67	11.257,78	17.313,15
8	24.269,50	4.151,81	11.163,97	17.714,11
9	24.065,55	4.281,60	11.070,15	18.128,58
10	23.861,61	4.415,13	10.976,34	18.557,16
11	23.657,66	4.552,49	10.882,52	19.000,47
12	23.453,72	4.693,77	10.788,71	19.459,14
13	23.249,77	4.839,07	10.694,89	19.933,85
14	23.045,82	4.988,49	10.601,08	20.425,31
15	22.841,88	5.142,12	10.507,26	20.934,26
16	22.637,93	5.300,05	10.413,45	21.461,45
17	22.433,99	5.462,40	10.319,63	22.007,71
18	22.230,04	5.629,25	10.225,82	22.573,86
19	22.026,10	5.800,71	10.132,01	23.160,78
20	21.822,15	5.976,88	10.038,19	23.769,38
21	21.618,21	6.157,86	9.944,38	24.400,63
22	21.414,26	6.343,76	0,00	9.814,93
23	21.210,32	6.534,67	0,00	10.322,63
24	21.006,37	6.730,71	0,00	10.855,59
25	20.802,43	6.931,98	0,00	11.414,98

cash flow change without repayment of the loan for 10 years, will be positive amounting to € 279.165,40. This amount represents the surplus, which the solar photovoltaic installation will be able to gain for 25 years, to create additional economic resources to the balance of the company.

Period (years): the years of guaranteed use of photovoltaic modules. In fact the installation has a longer life but the net energy output decreases with the years and moreover the warranty period is set to 25 years.

Generation (kWh/year): the annual generation of the installation based on data for the sun light in this region.

Electricity saved (€): the saving/economy obtained due to own generation, deducted from the bill/account in the receipt.

Energy bill/account (€): this is the economic value, obtained due to energy generation (promotional tariff value multiplied by the kWh generated).

Profit (€): this is the economy/saving made (the sum of avoided costs as per the receipt and energy bill amount), updated with the average annual inflation rate of 2,1%.

Results:

APPENDIX 1

Energy bill/account in Italy

The criteria for energy bill/account adoption in Italy are specified in Decree 387 dt. 2003, published in the Gazette No. 181 dt. 05.08.2005, with which the government adopts Directive 2001/77/CE regarding promotion of the electricity generated from renewable energy sources (refer to art. 7, Decree 387/2003). In fact the energy bill specifies the criteria for the promotion of electricity generated by low capacity installations - 1 kW to 1.000 kW. For the construction of instalaltions subsidies will be extended against applications to natural and legal persons (including public persons and residential apartment houses) for a period of 20 years.

The amount of promotional tariffs for photovoltaic installations for 20 years (applications from 2005-2006) varies according to installation capacity.

- Installations with a capacity of 1 to 20 kW 0,445 €/kWh;
- Installations with a capacity of 20 kW to до 50 kW 0,460 €/kWh;
- Installations with a capacity of 50 kW to 1.000 kW 0,490 €/kWh;

The new promotional plan envisages the installation (by the local distributor) of a fiscal electric meter in the lower part of the inverter. Thus all the electricity generated by the photovoltaic system will be registered based on which the portion corresponding to Energy bill relief will be calculated.

Moreover all the energy generated by the solar installation can be used by the same consumer.

Hence this “mixed” system enables the “saving”, made from the energy consumed by a customer and the excess energy provided to the grid to be added to the “profit” obtained from the Energy bill/account. Economic benefit of photovoltaic systems comes from:

1) The revenues from all the kWh, generated by the an installation (part of the Energy bill/account)

2) The savings made due to the consumption of photovoltaic kWh + the use of excess energy (kilowatts fed to the local power grid, because they have not been used by the consumer). This is done in the following ways:

a. deducting from the bill/account as per the receipt in case of installations having a capacity of up to 20 kWp (net metering)

b. sale to preset tariffs (lower than the Energy bill/account/ tariffs), in case of installations having a capacity of over 20 kWp.

Three cases:

Case 1. Installations/systems having a capacity lower than 20 kW: the saving (to be deducted from the following bills/accounts) of photovoltaic electricity used by consumers and/or provided to the local power grid, can be added to the promotional tariff. Therefore, net metering applies, i.e. as stipulated in Resolution 224 of 2000, which determines the conditions of exchange at the location of energy generated by photovoltaic installations having a capacity of up to 20 kW (exchange price is specified in the electricity supply contract- an average price of about 0,15 €/kWh).

Case 2. Installations having a capacity of over 20 kW inclusive: the saving made from the own consumption of photovoltaic electricity as well as the revenues made from selling excess amount of energy to the local grid can be added to the promotional tariff. This was stipulated in Resolution 34 of 2005, which determines the prices of electricity provided to the power grid: 0,095 (to 500 thousand kWh/year), 0,080 (from 500 thousand to 1 million kWh/year) and 0,070 (from 1 million to 2 million kWh/year). However, a competitive mechanism is envisaged for the tariff in case of installations having a capacity of over 50 kW.

While with the capacity mentioned above (1-20 and 20-50 kW), the promotional-tariff installations are listed according to the date of application, the installations over 50 kWp are listed based on the value of the requested promotional tariff: priority is given to applications requesting a lower promotional tariff. Moreover, with the installations having a capacity of 50 to 1.000 kW, the person responsible for the installation is to present a guarantee (to the amount of 1.500 € for an installed kWp), undertaking to pay default penalty in case of failing to implement the installation within the time limit envisaged in the ordinance. With the existence of such a requirement there is a risk that just the projects of large industrial groups will be able to be implemented.

The expenses for photovoltaic installation promotion are not chargeable to the state, and shall be covered by deduction from the electricity tariffs of all consumers (tariff components A3); such deduction should not exceed 0,0014 € for every kWh.

The decree stipulates also that by 2015 the cumulative installed capacity nationalwide is to reach 300 MW, this being not enough ambitious target taking into consideration the current development of the market.

Ways and place of filing the applications: There are dates in the year, which are the deadlines for the review of the groups of applications filed: 31st December, 31st March, 30th June, 30th September.

A candidate is to prepare a preliminary design and send it together with special forms to the so called “Initiator” – the organization authorized for application collection and selection. The preliminary design is to include a technical specification stating as follows:

- installation location;
- installation capacity;
- input voltage to the inverter;
- characteristics of the photovoltaic modules;
- characteristics of the inverter;
- expected annual generation of electricity

Within 60 days the initiating body shall publish the list of selected candidates, which is based on the dates of application submittal for systems from 1 to 50 kWp, and depending on the requested tariff for systems from 50 kWp to 1 MWp (the first positions on the list of selected candidates are for the ones requesting the least, i.e. lowest promotional tariff).

Calculation of capital pay back time

This is an example of a simplified calculation of the expenses and time for capital pay-back/return using an energy bill/account of a hypothetical photovoltaic installation of 2 kWp (an area of 16 sq.m.) in a residential dwelling in central Italy. Let’s assume that installation consumption is 3.000 kWh/year.

Turn-key cost (calculated): 14.000 € + 10% VAT = 15.400 €

Generation in Central Italy (2 kWp) = 2.600 kWh annually

Profit from the sale of kWh of photovoltaic energy = 2.600 x 0,445 € = 1.157 € annually

Saving from the increased expense of consumed energy (= kWh generated using a photovoltaic system; in this case just 400 kWh will be effectively paid to the electric company) = 2.600 x 0,16 € (average expense for electricity of families) = 416 € per year

Total annual economic benefit = 1.157 + 416 = 1.573 € per year

Installation pay back time = 15.400 : 1.547 = ~ 9,8 years

Investment has been paid back by this time and we start to profit from the installation.

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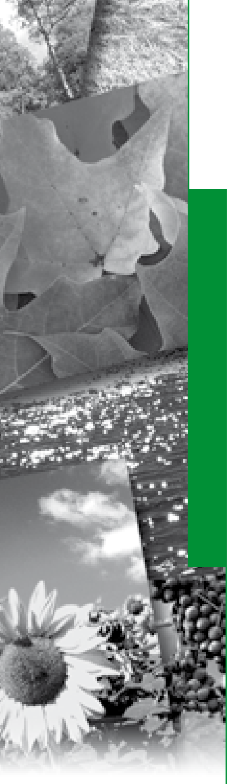


WIND ENERGY

Introduction

Wind Energy in Europe

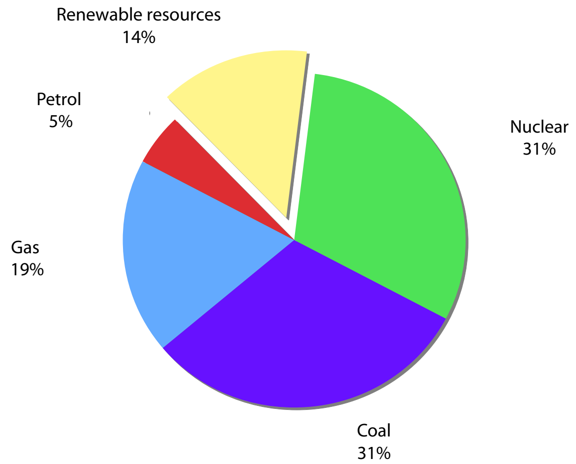
Wind energy today ranks among the fastest developing energy technology branches in the world. In practice, Europe is dependant on the import of conventional energy resources such as petrol, coal or gas. The ratio of energy production in the EC for 2003 is as follows:

Without doubt, Europe has particularly high wind potential. According to the Wind Atlas of Europe, which depicts the events in the end of 80s, the greater part of the countries comprising the EC, have sufficient wind resource, particularly those located near the Atlantic Ocean. No doubt, regions, such as Navara (Spain), that at present cover about 50 % of their energy needs with wind energy, have not been classified as such in the mentioned atlas. This can be explained by the significant technological development of the wind generators, which with every passing day allow better and better utilization of the wind resources.

Due to that development, numerous industrial plants have been established and tens of thousands work places created for a rather sufficient period of time. European companies are world leaders in the production of wind turbines and technology, occupying about 80 % of the world market.

The White Paper of the European Commission, published in 1997, sets the target for the 15 countries of the EC to achieve 40.000 MW wind energy production by the year 2010. But actually still in 2005, these 15 countries register

Electric energy resources in the EC for (2003)



above 40 000 MW wind energy production, thus the target is achieved five years ahead of the deadline.

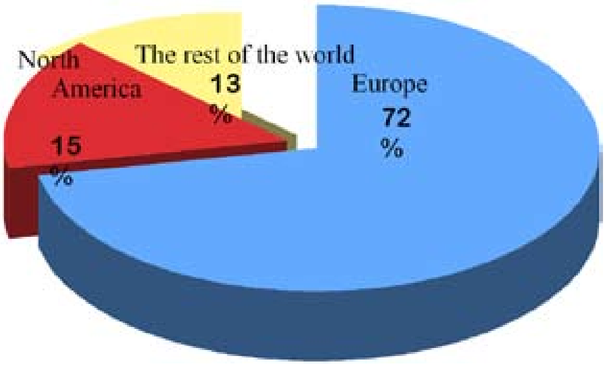
The EWEA (European Wind Energy Association) report "Wind Force 12", determines the strategic lines for how the wind energy industry – a sector whose turnover amounts to seven billion Euro per year to reach seventy-five billion Euro per year by 2020. The report also details the possibility for wind energy to cover 12 % of the electric energy world needs by the stipulated year.

There are the countries that hold the leadership in this sector: Germany, a world leader in wind energy production; Spain, which occupies the second place in the world and whose target is to reach 20.000 MW by 2012; and Denmark, which is head in the field of wind equipment technology and production.

Wind capacities installed in EC (2005)		
Place	Country	Installed capacities (MW)
1	Germany	18.428
2	Spain	10.027
3	Denmark	3.122
4	Italy	1.717
5	The United Kingdom of Great Britain	1.353
6	The Netherlands	1.219
7	Portugal	1.022
8	Austria	819
9	France	757
10	Greece	573
11	Sweden	500
12	Ireland	496
13	Belgium	167
14	Finland	82
15	Poland	73
16	Luxemburg	35
17	Estonia	30
18	Latvia	26
	The Check Republic	
19	Hungary	17
20	Lithuania	7
21	Slovakia	5
22	Malta	0
	Cyprus	
	Slovenia	
TOTAL European Union		40.475

Source : EWEA

At the end of 2004, Europe makes up 72 % of the total wind energy capacities in the world and continues the construction of new wind parks.



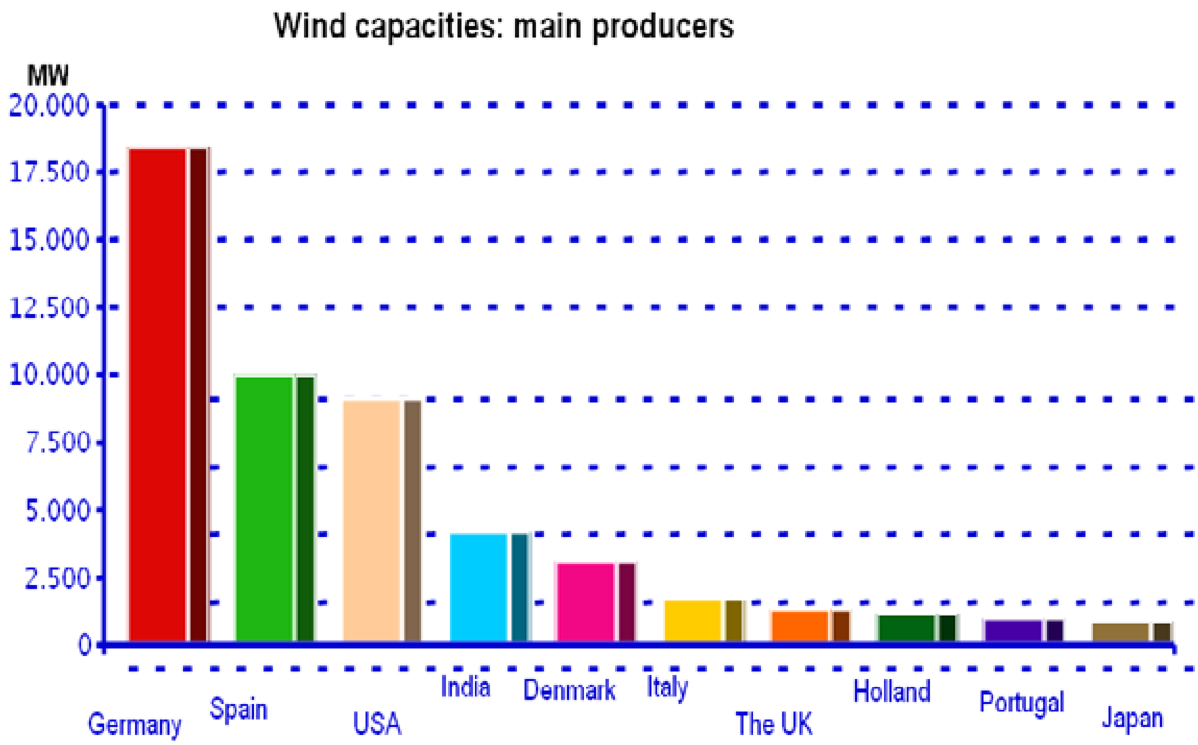
Europe	34.190 MW
North America	7.196 MW
The rest of the world	6.188 MW
Total	47.574 MW

Source: EurObserv'ER 2005 - Windpower Monthly 2005

The following table indicates the countries occupying the first ten places in the world by production of electricity from wind energy, 7 of them are European:

Installed wind capacities (2005)		
Position	Country	Installed capacity (MW)
1	Germany	18.428
2	Spain	10.027
3	The Unites States	9.149
4	India	4.228
5	Denmark	3.122
6	Italy	1.717
7	The United Kingdom	1.353
8	Holland	1.219
9	Portugal	1.022
10*	Japan	940* (data from 2004)

Source : EWEA, AWEA EurObserv'ER 2005 - Windpower Monthly 2005



European Strategies for the Development of Wind Energy

The European governments have proposed ambitious but realistic initiatives for development of the renewable energy resources, among which wind energy occupies particularly significant place.

The European Union, with its European Parliament and Council Directive 2001/77/CE of 27 September 2001 regarding the promotion on the internal market of electricity produced from renewable energy resources [Official Journal L 283 of 27.10.2001], stipulates increase of the renewable energy resources share in the production of electricity on the international market, as well as establishing the basis for a future common European market for them.

The development of wind energy in this directive is perceived in the spirit of the rest of the European renewable energy resources programs such as “Intelligent Energy – Europe” or the campaign ”Sustainable Energy for Europe”.

The Directive, elaborated in answer to the White Paper regarding the renewable energy resources supports the target to achieve in 2010 renewable energy resources share of 12 % from the gross national consumption of electricity in the entire Community, and the electricity produced from these renewable resources to be 22,1%. This prospect is an important part of the required measures to be taken in order to implement the commitment of the EC under the Kyoto Protocol of 1997 regarding the reduction of the harmful greenhouse gas emissions.

At present the EC companies are world leaders in the field of technology and construction of wind generators. The Directive aims at encouraging the increase of the share of that type of energy, taking at the same time in account the internal market laws.

By this Directive, the EC also seeks the costs for interconnecting of the wind energy electricity system to the grid not to be an obstacle to the development of this energy resource, which offers economic advantages and protection of environment. At the same time, it wants to guarantee appropriate functioning of the internal market, which would ensure equal conditions for all producers.

In this connection the member states should establish legal frameworks or require from the operators of the transmission and the distribution systems:

- To guarantee the transmission and the distribution of electricity produced from renewable resources. The member states could give a priority access of the electricity produced from such sources to the electric grid within frames allowing the normal functioning of the national electricity transmission networks;
- To elaborate and publish norms regarding the costs for technical adaptation, related to the integration of the new renewable energy producers to the electric grid. The member states can request the operators to bear such costs completely or partially;
- To elaborate and publish respective typical norms for the distribution of the costs for installation of the system components and for reinforcing of the grid among all producers that make use of it;
- To submit to the new producers, who have decided to connect to the grid, complete and detailed assessment of the costs, resulting from the interconnection.

The member states should guarantee that the transmission and the distribution fees and charges shall not be discriminating towards the electricity produced from renewable resources;

The member states shall be obliged to investigate the necessity of two-way electrometers (in order to provide for purchasing of electric energy from the grid in case the wind energy production is insufficient).

In regard to the respective rules concerning sea wind energy, the Commission is committed to review the obstacles that could have hindered the development of sea wind energy, as well as the obligations for meeting the requirements for protection of environment. The Commission supports the surveys and the studies for improvement the turbine technology and stabilizing of the grid, as well as the intentions for reaching above 20 % distribution of wind energy.

Wind energy is a clear example of how the research and development supported by the EC for more than 20 years, assign Europe a leading role in the promising high technology sphere, which creates more than 85,000 working places in the Community. The European research and development strategy covers nine priority zones:

- Economics, politics and market
- Environmental and social impact
- Design of wind generators and components
- Testing, standardization and certification
- Integration to the network, energy systems and resources assessment
- Operation and maintenance
- New possibilities
- Overseas wind technology
- Megawatt and multi megawatt technology

Prospects for use in rural areas

Wind energy is of a particular great significance for the electrification of rural regions, particularly in places where there is no conventional electricity supply. As winds in their nature are cyclic (night/day, season), unstable and determined by the geographic conditions, microclimate, meteorology, etc., it is impossible to ensure continuous supply in isolated systems, therefore local consumption decisions are oriented towards interconnection to or establishing of grids with another support (back up) system, i.e. mixed systems, where wind energy is used to save fuel, or is combined with other renewable resources. In small systems, energy accumulation systems (batteries) are usually included.

In any case, wind energy can practically be used at every place, with different capacity installations adapted for different necessities. Big wind parks today are capable of producing sufficient electricity in order to satisfy the electric energy needs of thousands of families; small dimensions turbines can service rural regions or settlements isolated from the electricity transmission grid.

Wind energy applications in rural regions can be differentiated as follows:

- Supply of isolated zones ("stand alone"- independent and "off-grid"- not connected to the grid)

With regard to electricity supply there are isolated zones, where it is not economically feasible to construct electricity transmission grid. Speaking of a limited number of rural tourism places, camps, farms, mountain shelters, season houses, etc. In such cases it is possible to use wind generators with small dimensions, together with accumulation system (battery) and hybrid systems (with photovoltaic panels or diesel generators).

Small wind generators can also be used for power supply of telecommunication systems such as retranslators, mobile telephone antennas and others of that kind, which are installed in isolated zones.

Wind turbines can be successfully used and for pump and drain installations, for public lightning and for power supply of preserved nature zones.

-"on-grid" systems and "grid-connected" systems

According to the legislation in force, the owners of wind energy micro installations can use the energy produced for their own needs and supply the excess to the grid by selling it to the distribution company. On their part the producers of energy from renewable resources have the right at any time to be supplied by the distribution company with the energy they need for their activity paying for it on the basis of the respective tariff.

Wind parks are constructed primarily in rural regions thus ensuring both economics development and work for the local population.

In the future wind energy shall not only be used for electricity production. There are other possibilities, for example using wind energy in sea water desalinating plants and hydrogen production plants (in research of hydrogen as future automobile fuel). Sea water desalination can solve the shortage of potable water in arid and semi arid regions both for household consumption and irrigation.

Environmental impact

Before detailing the possible negative impacts of wing energy on environment, it is relevant to point out its advantages from environment protection point of view:

Wind energy production does not pollute the environment, it is inexhaustible, and there are no harmful gas emissions, which bring about avoiding global climate changes. The adverse impacts resulting from the production, processing, transport and burning of petrol, coal and other fuel are thus prevented.

In contrast to conventional energy sources, wind energy:

1). does not influence in any way on water resources, both with regard to consumption and pollution with waste substances, nor due to change in its direction or power;

2). does not generate toxic gases, has no contribution to the green house effect and acidic rains. Each kWh produced from wind energy instead of coal prevents the emission of:

- 0,60 kg CO2 (carbon dioxide)
- 1,33 g SO2 (sulphur dioxide)
- 1,67 g NOX (nitrogen oxides)

3). does not generate hazardous by-products, nor toxic pollutants.

A park of 10 MW:

- Prevents the emission of 28.480 t CO2 per annum
- Is equal to a consumption of 2.447 t petrol
- Produces electric energy for 11.000 families
- Provides work for 130 people per annum during the design and construction phase.

On the other hand, the min negative impacts of wind parks on environment are the following:

4). impact on environment resulting from infrastructure construction (access ways to the park location, high voltage lines, etc.)

5). noise

6). visual impact

7). impact on birds

The less developed is the park location zone, the bigger the impact of infrastructure is. The availability of access roads, the lack of trees or the existence of high voltage transmission lines reduces the impact of the park on environment.

The noise from the wind generators can be of different origin: mechanical noise and aerodynamic noise:

The mechanical noise results from the functioning of the wind generator components (metal elements, shafts, and generator). Most of the components are designed in such a way that the noise is of the lowest possible level, designs are continuously improving in order to reduce vibrations. Due to the significant design improvements, today, in practice, noise insulation is no more necessary.

Aerodynamic noise results from impact of wind with the wind generator. The blades should intercept the wind in order to transfer its energy to the rotor and noise is generated as a consequence. The surface of the blades is very smooth and therefore the greater part of the noise is generated by the rear edges of the blades. Due to the improvements made in the aerodynamic design of the blades, their performance and efficiency was increased and the acoustic emissions reduced at the same time. The noise is related with the rotation speed of the blades and therefore wind generators with a big diameter operate with lower speeds.

With the further improvements made, today acoustic pollution caused by modern wind generators is negligible, see table below.

As for the visual impact, wind generators are located in open wind exposed places, therefore they are readily visible.

The towers are generally painted in colours that merge with the environment, and have simple geometry and design that contribute to their matching to environment.

No doubt, the perception of that visual impact is subjective. The surveys made in different countries (Denmark, the United Kingdom, Germany and Holland), show that the people living near wind parks have a more positive attitude compared to the inhabitants of highly urbanized zones.

Noise level dB (A)	Example	Effect. Long-term impact
0	Audibility threshold	Complete silence
20-40	A field at night	Complete silence
35	Quiet bedroom	Silence
35-45	Wind park at 350 m	Silence
40	Library	Silence
50	Conversation near to a wind generator in operation	Silence
55	A car with 65 km/h at 100m	Slight vexation
60	Crowded office	Slight vexation
65	A truck with 50 km/h at 100m	Vexation
70	Aspirator	Vexation
90	A noisy truck or motorbike	Strong vexation. Harm
100	A mowing machine	Strong vexation. Harm
120	A nearby siren/horn	A slight pain
140	Aircraft carrier	Pain
150	Taking off of an airplane at 25m	Bursting of the ear drum

It can be concluded therefore that the adequate location of wind parks in environment is the key to their more tolerant acceptance. Taking into account that wind generators do not produce any harmful emissions and the energy source is free and inexhaustible, a wind installation always has much less negative impact on environment compared to nuclear and thermal power plants, and even to hydro power plants, which require extensive infrastructure and indisputably have much greater impact on environment.

Finally, particular attention deserves the impact on birds. Birds very often crush into windows of buildings, high voltage lines, poles, trains and all type of motor vehicles. The studies made till now by the Royal Bird Protection Association of Great Britain, the National Environmental Research Institute of Denmark and other organizations show that the wind parks do not represent a significant risk for birds. The high voltage lines, for example cause the death of much more birds per annum than the wind generators, but mostly for the death of inexperienced or sick individuals.

Various measures are taken in wind parks for reducing the impact on bird fauna: burying of the cables, air line signals, use of bright colours or different sounds, reducing the rotation speed, adequate distance between the generators, closing of illegal landfills, etc. The investigations, mainly by radar tracing, show that the migrating flocks generally avoid the wind parks or fly by at a safe distance. Of course, there are species that need more time to get accustomed to the presence of the wind parks and this should be taken into account when locating the facilities. It should also be taken into account that such studies have not been made during strong winds, as well as at sunrise or sunset, when light is poor.

In conclusion, construction of wind parks should be avoided in the vicinity of bird preserves or near the zones of their migration, and the preventive measures should be increased (burying of cables, signalling, etc.).

Finally it should be pointed out that wind parks can cause interference with telecommunications, which can be avoided by installing adequate antennas – translators.

Technological features of wind energy

Location of wind sites

For each individual wind park it is necessary that professionals carry out detailed studies in order to determine the most appropriate location of the future park. These professionals should know perfectly well both the measurement systems and the wind characteristics.

The location of a single wind generator or a wind park should be carefully selected as the energy to be produced and mainly the profitability of the investment depend on the wind velocity and its persistency.

- The output capacity is proportional to the wind speed to the power three. A small difference in the speed can lead to a big difference in the output capacity.
- Wind persistence is important for the continuous energy generation; the stopping of the wind generators can create supply problems in wind parks, although this is not that important for small domestic plants. Too strong wind blasts, on the other hand can be risky for the plant due to strong impact on it.

The energy production also depends on air density which decreases with height. For the correct measurement and reading of this parameter a barometer is required.

There is always wind on the earth surface but its strength constantly changes. It originates from the solar radiation which heats the surface of the earth non-uniformly. As the warm air expands and therefore is less dense than cold air, zones with high and low pressure are created in the atmosphere; this misbalance leads to transposition of the atmospheric layers, i.e. wind.

The energy generated from wind in a given turbine is due to its velocity (kinetic energy). Generally, the vertical component of velocity is not constant with the increase of height. Due to the friction with the surface of the earth, the wind velocity is lower near the surface of the earth and increases with height. The rougher and the more curved the surface is, the more barriers there are to wind.

For this reason wind blows with lower velocity in valleys and kettles and with much greater in mountains and uplands. Due to lack of barriers, wind velocity is greater in the sea than on land. Therefore the best places to locate wind mills are inside the sea or on hills near the shore with less vegetation

In navigation wind velocity is measured in knots and Beaufort scale is applied. This scale was introduced in the 19th century by Admiral Beaufort and it is still in force.

Beaufort scale	Description	Effects	Speed		
			Knots	m/s	km/h
0	Calm	Smoke rises vertically	0-1	0-0,5	0-2
1	Light air	Direction of wind shown by smoke drift, but not by wind vanes	1-3	0,5-1,5	2-5,5
2	Light breeze	Wind felt on face	4-6	1,6-3,3	5,5-11
3	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag	7-10	3,4-5,4	11-19
4	Moderate breeze	Raises dust and loose paper	11-16	5,5-7,9	19-29
5	Fresh breeze	Crested wavelets form on inland waters	17-21	8,0-10,7	29-39
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires	22-27	10,8-13,8	39-50
7	Near gale	Inconvenience felt when walking against the wind	28-33	13,9-17,1	50-61
8	Gale	Wind breaks twigs off trees	34-40	17,2-20,7	61-74
9	Severe gale	Wind removes chimney-pots and slates	41-47	20,8-24,4	74-87
10	Storm	Considerable damage	48-55	24,5-28,4	87-102
11	Violent storm	Wide spread damage	56-63	28,5-32,6	102-117
12	Hurricane	Catastrophic hurricane	> 64	> 32,7	>117

In researching wind effects the unit m/s is generally used.

A preliminary study is required in order to determine the average wind velocity. It consists in gathering meteorological data and measuring the wind velocity with anemometers. The perfect way to measure wind velocity is at the site where the future turbine shall be constructed and to fasten the anemometer on a pillar at the same height at which the turbine shall be located.

Wind speed is measured by means of anemometers. The most frequently used model is anemometer with vertical axis and three hemispheres that catch the wind. The rotations per second are registered electronically.

There are other models as well that use ultrasound, laser or electrically heated wires. These anemometers are rarely used and are most appropriate for arctic or very cold climate, where the formation of ice can cause malfunctioning of the mechanical anemometer.

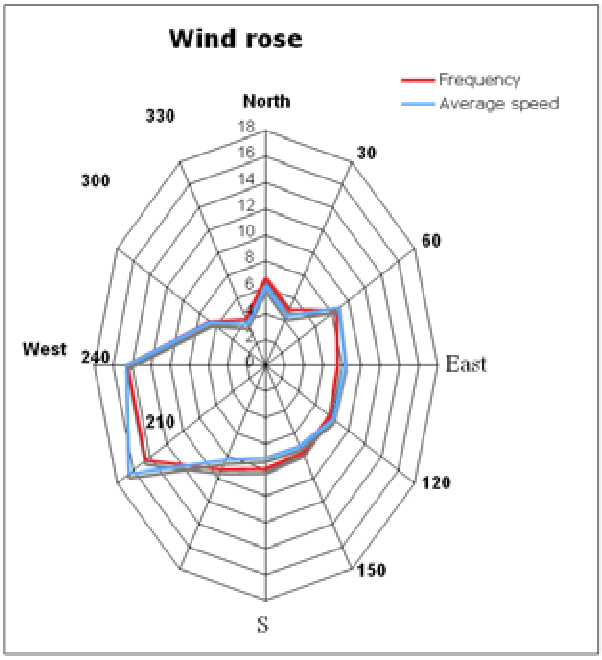
It is also very important that the chosen anemometer is a good quality one. As the force is proportional to the speed to the power three, an error of 10 % in the measurement leads to an error in the estimation of the force of 1,13, which means 33%.

With regard to the domestic installations, the turbines used are with small dimensions, lighter and work with weaker winds. This type of installations are also used as complementary to alternative electricity production systems (solar panels, diesel electric generators or connected to the grid), and therefore eventual measurement error is not of such big importance.

For small installations such studies are rather expensive and long and therefore it is normal just to make an inspection of the plants and trees around and to study the meteorological conditions in the region.

For a feasibility study for the construction of a wind park, however, the use of anemometers with admissible error of 1 % is recommended. Their price shall be compensated by avoiding wrong economic evaluation that can be catastrophic.

With the data obtained a wind rose is drawn that can have 8, 12 or 16 axes. In order to draw this diagram, the wind frequency in per cents and the speed of the wind coming from each direction should be taken into account.



The frequency shows the time during which wind blows from each direction in percents. The average speed is multiplied by the frequency and is represented in percents in order to show the contribution of each direction to the wind speed.

The wind rose is unique for each specific place. By observing it, the location of the wind generator can be determined: if a big part of the wind energy is coming from a specific direction, it is assumed that this direction is free from obstacles. It can be seen from the above example that the prevailing direction is west-southwest and unquestionably in the directions north, north-northwest and north-northeast much less energy is obtained.

The wind rose can vary from year to year; therefore it is good to have data from the different years in order to obtain more realistic average speeds. Usually, local measurements are made for a year and are compared to the meteorological data from the near stations for a much greater period of time.

Besides the economic criteria (operation hours of the park, terrain expenses, infrastructure costs, etc.) when the most appropriate location for a wind park has to be chosen, there a number of criteria that should be taken into account:

- Power criterion: if in the region there are no other competitive energy sources, the construction of a wind park with a big potential situated on a vast area with the necessary transmission lines can be of interest. In this case the project can be economically viable both due to the dimensions of the installation, as well as from the electric infrastructure and the other installations.

In the reverse case, it will be much better to construct a small wind energy installation at a short distance to the grid.

- Grid capacity criteria: before constructing a new wind park, it is good to know to what extent the nearest electric station satisfies the region with electricity. The distribution company or the competent administrative authorities can give information to what extent the grid in the region can take the electric energy produced by the wind park. If it is satisfied and cannot take more energy, the wind park shall not be able to sell its excess electricity to the electricity transmission grid.
- Environmental criteria: locations that represent a risk for birds or has other adverse impacts on environment should be avoided.
- Political criteria: before designing a new installation, it is good to study the public opinion with regard to wind energy at national, regional and local level. Although the European or the national policy can have favourable attitude to energy from renewable resources, in certain cases the construction of wind parks can be met with opposition by the local public or due to other interests.

Wind mills: plant types

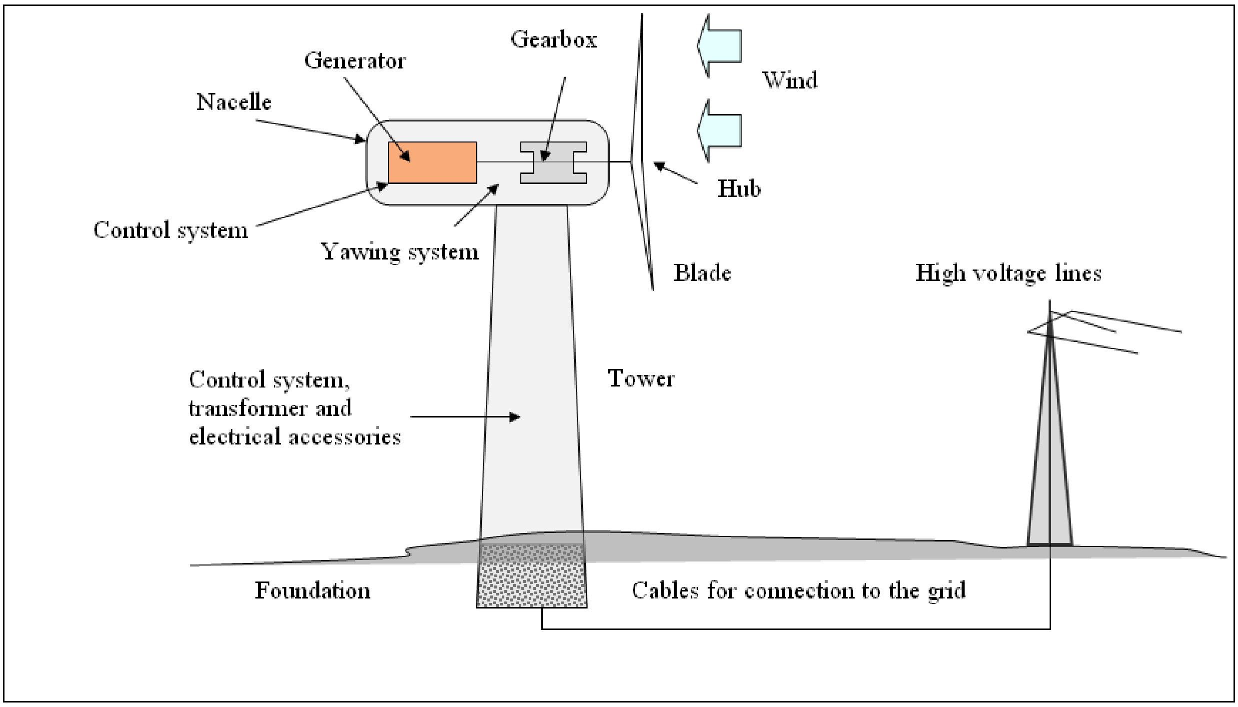
The wind turbine is a machine that transforms the kinetic energy of wind (the energy resulting from the motion of air) into another type of energy: mechanical or electrical.

Traditionally wind energy is used for transformation into mechanical energy in mills, water pump stations, saw mills, etc.

Modern wind turbines that produce electric energy are also called wind generators.

There are two types of wind generators:

- **with vertical axis**, whose main axis is perpendicular to the surface of the earth. These are the Savonius turbines whose design resembles anemometer and Darrieus that resembles a mixer. Their advantage is that the generator and the gear box can be put near the ground, thus significantly reducing the weight that has to be supported by the tower; and also the turbine does need to



orient in the direction of the wind.

- **with horizontal axis**, whose main axis is parallel to the ground. They are considered more efficient and at present are most used.

The wind generators have different components:

- **rotor**, which transforms the wind force into rotation of the axis. It includes hub and blades. The blades capture the wind and transfer its power to the rotor hub, which is attached to the low speed shaft of the wind generator. This shaft at its turn is connected to the multiplicator or the gearbox.
- **Nacelle**, which contains the electrical generator that transforms the energy of rotation into electric energy, multiplicator or gearbox that increases the rotation speed and hydraulic control system, yawing and shut down mechanism. The gearbox has on the rotor side the low speed shaft from which the motion originates, and on the other side the high speed shaft that rotates with about 1.500 rotations per minute, which allows the functioning of the electrical generator when connected to the grid. Rotor brake system is installed on this high speed shaft. The modern tendency is to use wind generators without multiplicator, they are called multi-pole generators.

Almost all wind generators with horizontal axis employ enforced yawing system, i.e. electrical motors mechanism that maintains the rotor oriented in the optimal direction against the wind at any moment. The yawing mechanism receives signals from an electronic controller connected to a wind vane located at the rear part of the nacelle. The wind vane detects the speed and the direction of the wind.

Wind generators with small dimensions use the passive orientation principle, with orientation tail or helm serving as a wind vane.

If the rotor is not located perpendicular to the wind, it is said that the turbine has an orientation error. This means that only a small part of the wind energy shall be captured by the rotor, and besides, this part of the rotor that is exposed frontally to the wind, shall be subjected to a greater pressure.

The nacelle also includes hydraulic part that drives the blades rotation system and a brake system. As a great amount of heat is generated when the wind generator is in operation, a cooling system should be installed in the nacelle, which uses mostly the wind for this purpose.

- **tower** that supports the nacelle and the rotor. Its construction can be of pipes or sheets. The height of the tower increases more and more with the installation of more powerful wind generators. For a 600 kW capacity, towers with 60 m height can be met; and for a capacity of 2 MW, as those presently installed, the towers can be more than 75 m high. The optimal height if the tower is calculated taking into account the following prerequisites:
- the price of one meter of the tower: 10 additional meters cost approximately 15.000 €.
- The wind changes with the increase of height above ground level.
- The price for each kWh additionally produced energy.

Wind generators have a minimum life time of 20 – 25 years, although it is possible some of them to be replaced by more powerful plants before this period has expired.

Wind generators with horizontal axis can be also classified with regard to the number of blades, the location of the rotor in the machine, the attachment of the blades to the hub, as well as the dimensions and the capacity.

Number of blades:

- **Machines with many blades**: these are the classical

water extraction pumps. They can capture even wind with very low speed and are an excellent example of utilization of the torsion forces. They are used for mechanical works.
- **Fast machines:** these are wind generators with horizontal axis. In order to generate electricity they need to rotate at a high speed; they capture the wind energy by the aerodynamic design of their blades, not by their resistance.

Micro turbines can have 5 or 6 blades; small wind generators can have two blades; there is no question, however that best performance is achieved with three blades rotors, as the ones used in big capacities wind generators.

The reason for this differentiation is that with two bladed rotors, the forces to which the blades are subjected do not compensate along the length of their surface: when the blades are in vertical position, the upper blade receives a much stronger impact than the lower one, which remains protected by the tower and the turbulences forming around it. This different loading of the blades requires a teetering hub, which complicates the plant design. Besides, the two-bladed rotor rotates faster and generates more noise. When the turbine rotates to orient towards the wind, the rotation is more instable.

With small wind generators, these forces are more easily controlled by appropriate support of the machine, thus achieving a more stable rotation mode.

Undoubtedly, big wind generators use three blades. With this construction the generated forces distribute and compensate each other better. The turbines with three blades generate less noise, they are more stable when oriented to the wind, and their productivity is greater.

Of course experiments are performed with one-bladed turbines. With these turbines the same problems occur as with the two-bladed, but the speed and noise are even greater and they require a counter weight for balancing.

Rotor position:

The position of the rotor towards the wind influences the entire design of the machine: location of the blades, shape of the nacelle, brakes control and orientation system.

- **Wind generators** at the windy side: these wind generators are located in such a way that the rotor faces the wind. Most of the wind generators, as well as all wind generators with small capacity are located at the windy side (upwind type).
  Their main advantages are the low manufacturing price, better wind utilization (the tower shade is avoided) and a better distribution and compensation of the loads.
  Their main disadvantages are that they require yawing system to maintain the rotor in its position against the wind, and that the rotor should be more stable and to be installed at a certain distance from the tower (the wind starts diverting before reaching the wind generator).

- **Wind generators at the lee side:** in this case wind first meets the nacelle. They are distinguished mainly by the conic location of the blades. This system is used in certain medium and large dimensions turbines.
  Their main advantages are the possibility for automatic orientation without yawing mechanism, as well as the fact that they use the wind blowing for cooling.
  As the blades, throughout their whole trajectory, are subjected to variable wind forces, the entire installation is subjected to a big loading. Therefore they are used primarily in medium size turbines, as the orientation and the cooling are simplified.

Attachment of the blades

The blades can be installed in the hub or be fixed, or in such a way that they have possibility for certain motion in order to resist more or less the wind.

- Wind generators with fixed blades: the blades are fixed and cannot rotate around their axes;
- Wind generators with movable blades: the blades can rotate around their axes and therefore it is possible to adjust the wind impact angle. In case of strong winds the wind impact angle is regulated and thus the rotation speed of the blades is corrected.

Dimensions and capacity

Wind generators can be classified on the basis of their dimensions and more specifically, the dimension and the diameter of the rotor.

At present at the market there are diameters from 0,5 to above 90 m. These differences in the diameters not only determine the output power, but also their application and construction:

- Micro turbine or micro wind generator (50-250 W)
- Wind generators with small capacities or mini wind generators (250 W-1 kW)
- Domestic wind generators (1-50 kW)
- Wind generators with medium dimensions (50-750 kW)
- Wind generators with big dimensions (>750 kW)

Wind farms and wind parks

A wind park is a complex of wind generators located at an appropriate place for the purpose of producing electric energy.

Wind parks can be located on land or in the sea (off shore). The location on land is more frequently met, although in Europe the number of off shore wind parks increases.

Wind generators on land are usually located on hills or highlands, dominating the landscape around. These raised elevations have the advantage to receive more wind from each direction. There is also the so called hill effect: on the top of the hill, the wind speed is always greater; this is due to the fact that the air is denser at the upwind side and after reaching the top it starts expanding.

Off shore wind parks are considered to have less visual effect, as they look smaller from the distance; their towers are also lower as at one and the same height wind speed in the open sea is greater than on land. The interest in locating wind generators off shore is motivated by a number of advantages:

- In the open sea the wind speed is greater due to the lack of obstacles and it is much more constant.

- The availability of areas and wind resources is much greater than on land.
- The visual impact is less.
- Therefore wind parks with much bigger capacities can be installed.

As a disadvantage it can be pointed out the installation and the operation costs are greater due to the following reasons:

- The cement founding is much more expensive and complicated for execution;
- The electric transmission grid should be laid at the bottom of the sea.
- The towers are much higher as a bigger or a smaller part of them is under water.
- Maintenance is more complicated and more expensive.
- Sea conditions are corrosive and abrasive, and as a result the wind generator components are subjected to a bigger wear and tear.

The better wind conditions, areas availability, the necessity to make profitable a big investment, as well as the big distance to populated regions determine the installation of wind generators with big dimensions in sea.

The impact on sea mammals and other sea species is not studied (wind generators produce vibrations that may have impact on sea organisms).

In both cases, with wind parks on land and off shore parks, the park effect should be taken into account: each wind generator when producing electricity stops the wind that passes through it. Therefore the wind generators should be maximally remote from each other in the direction of the prevailing wind. On the other hand, the bigger is the distance between them, the greater area they shall occupy and more expensive the cabling.

In practice, the turbines in a park should be separated at 5 to 9 times the rotor diameter in the direction of the prevailing winds, and at 3 to 5 times the rotor diameter in the directions perpendicular to the prevailing winds.

Generally, the energy loss in a wind park is usually between 2% and 5%.

Plant sizing and energy efficiency

The output power produced by a wind generator depends on the surface of its blades and hence on their length, but at the same time it does not depend on their number. The power results from air flow mass and the kinetic energy of the air molecules, and is expressed by the formula:

$$P_U = \eta \cdot \frac{1}{2} \cdot \rho \cdot S \cdot v^3$$

where η is the total productivity of the turbine, S – the area covered by the rotor (m2), ρ - the air density (kg/m3) and v – the wind speed (m/s).

As can be concluded from the above formula, the power that can be obtained from a wind generator depends on the speed and more specifically the speed to the power three. Therefore an increase in the wind speed, for example, from 6 m/s to 12 m/s, increases the energy produced 8 times.

In the same way it can be concluded that the output power depends on the area. The greater the area covered by the blades, the bigger the output power.

The initial data required for adequate determining of wind generator dimensions is:

- Nominal capacity (initial specifications) Pn
- Nominal wind speed Vn

E.g. you need to know what capacity is required or wished to be installed, as well as the average wind speed at the place of the future installation. Also, in order to calculate the energy that the turbine will produce, you need to know the number of hours, calculated for functioning at average speed.

In case of domestic installation this data is sufficient. After that a turbine with appropriate capacity, nominal velocity and price is chosen, taking into account the fact that the production of electric energy shall depend on the hours in which the turbine has functioned.

The small dimensions models (50-250W) can be sufficient for supplying:

- Livestock food distribution systems
- Electrical herds or electrified fences/pailings
- Lighting of isolated buildings
- Antennas, retranslators

On the other hand, turbines with greater dimensions (1-4 kW or more), combined with accumulators (a set of batteries) and photovoltaic panels can supply sufficient electric energy in cases when connection to the grid is not possible:

- Shelters or houses for rural tourism
- Cattle sheds
- Isolated houses

Wind generators with capacity of or above 50 kW are usually connected to the electric grid.

In a wind park where different wind generators shall be installed, the turbine dimensions shall depend on the conditions of their location:

- Big turbines: their main advantage is that they allow for significant savings. That means that wind generators with big dimensions can supply with electricity at a price lower than that of small turbines. This is due to the fact that the foundations costs, construction of access ways, connection to the electric grid, electronic control systems, etc., do not depend on the size of the wind generator.

Also, in the zones, where it is difficult to construct a whole park, a single wind generator or a reduced unit with a higher tower can be installed. In this way wind resources are utilized more effectively.

- Medium size turbines: in case that the existing electrical grid is with a small capacity (as it is far from electricity production plants or satisfies low consumption needs), it is more appropriate to install small capacities, in order to avoid collapsing of the grid. Also, the electric energy produced by a wind park with different wind generators is characterized with fewer fluctuations, as they are balanced and neutralized.

Depending on the location of the park, it can turn to be economically more viable to install turbines with smaller dimensions, if this shall avoid the construction of new access ways or the use of big cranes.

On the other hand, with a big number of turbines, the risk is distributed in case of damage or temporary failure of one of the wind generators, for an example as a result of a lightning strike.

Calculation of the rotor diameter:

The minimum rotor surface for generation of the nominal output power is:

$$S \geq \frac{2P_n}{\rho V_n^3 C_{p_{max}}}$$

where S is the rotor area, Pn is the nominal power, ρ is the air density, Vn is the nominal wind speed and $C_{p_{max}}$ is the nominal power coefficient.

Besides, the diameter should be:

$$D = \sqrt{\frac{8P_n}{\pi \rho V_n^3 C_{p_{max}}}}$$

It is necessary to calculate one initial value of the nominal power coefficient, which represents the final productivity or the ratio of the theoretical capacity and the one practically obtained in the end. $C_{p_{max}}$ is between the following values:

- Optimistic case: Cp ≈ 0,45
- Pessimistic case: Cp ≈ 0,33

The effective diameter is calculated by taking into account that the hub and the connection of the blade to it do not receive energy from wind. Therefore the effective length of the blade should be taken into account: fp= $\frac{r_0}{R}$, where fp is the proportional part of the effective blade (that part of the blade that is actually used for obtaining energy from wind), r0 is the effective length and R is the total length of the blade.

The effective diameter shall be: $D_r = \frac{D}{(1-f_p)}$, e.g. twice the length of the blade, from where, after calculating the hub and the connection zone, the nominal power is obtained.

Connection to the power grid

The energy produced by the turbine can be accumulated in batteries or transmitted to the power grid.

Connection to the grid is an advantage as it saves both the installation of batteries and the discomfort not to have electricity when there is no wind.

It is obvious that big wind generators have to be connected to the grid as it is impossible to accumulate such amount of energy in batteries. For smaller size installations, it is important to have high voltage lines from 10.000 to 30.000 V nearby; otherwise the expenses for transmitting of the electric energy shall be enormous.

On the other hand, the existing power grid in the proximity should be capable to receive the electric energy produced by the wind generators, e.g. it should be with adequate parameters.

Connection to the power grid can be direct or indirect. Direct connection to the grid means that the electricity produced by the wind generator is directly supplied to the power grid. Indirect connection to the power grid means that before the electric energy is supplied to the grid, it passes through a complex of electric equipment, so that the generated electricity acquire the same characteristics (voltage, intensity, phase, etc.) as the current in the grid.

Installation with a direct connection to the grid has a simplified functioning: when the wind generator produces sufficient energy (measured as electric voltage), a device called converter automatically connects it to the grid. The converter can in any moment maintain the voltage (output voltage) stable, by changing the intensity (output amperes) in correspondence with the electricity produced by the wind generator.

Apart from that the converter can switch the wind generator off the grid in case of collapse, failure of lack of wind. The wind generator remains stopped, without rotating and without being connected to the grid.

Most of the wind generators function at almost constant speed and that allows direct connection of the grid.

In case of indirect connection to the grid, the turbine generator functions in an alternating current circuit, separated from the grid. In this case the alternating current frequency can vary also because the turbine can move at a variable speed. All required components for indirect connection to the power grid are included in the panel for connection to the grid, as follows:

- Three-phase switch: it is used to initiate the stopping of the wind generator due to a short circuit in the alternator. The switch should always be in "Off" position, when any of the electric components of the wind generator is being maintained or repaired;
- Indicator or signal lamp: it is always lit when the turbine produces electric energy;
- Grid failure detector: this is a device detecting that the circuit remains closed. Otherwise, the brake system is actuated in order to prevent damage of the wind generator if excessive speed is reached;
- Voltage sensor: it closes the circuit when electric energy is produced, in case the connections are correct.
- Ammeter: it measures the intensity of the electricity produced.
- Transformer: serves to increase the voltage of the alternating electricity produced from 220 V to 380 V.
- Rectifier: transforms the alternating electricity produced into direct current. The reason for this transformation is that alternating current with varying frequency cannot be directly supplied to the grid; therefore it needs to be transformed into direct current with the help of thyristors or big powerful transistors;
- Inverter: transforms the rectified direct current into

alternating three phase current. In this case alternating current with frequency coinciding with the frequency in the public grid is generated. The inerter can be either thyristor or a big powerful transistor.

- Filter: this is a combination of inductors and capacitors that clear and modify the sinusoidal wave of the alternating current coming from the inverter and modify this wave in such a way that it is synchronized with the characteristics of the grid. The current coming out of the inverter is with sharp voltage fluctuations; passing through the filter, current is smoothed before being fed to the grid.
- Electric energy meter: it registers the electric energy produced in kW.
- Thermal switch: protects the system and allows its switching off.

The main advantage of indirect connection is that it allows the turbine to function with variable speed. In case of strong winds, the excess energy makes the rotor rotate faster and excess energy produced is accumulated in the form of rotation energy until the wind lasts. In this way, the loading that has to be born by the blades and the tower is reduced. Another advantage is the possibility to control the phaseless current in relation to the grid (reactive power) thus improving the power quality of the grid. As a disadvantage, the bigger price of the indirect connection can be pointed out.

To connect to the grid, a contract should be signed with the electric company to which the energy will be sold. In certain cases, the company can request payment of a fee for connection to the grid.

Economic considerations

Plant costs

The price of electric energy produced from wind depends on the location. The wind generators location determines the investment costs and the profitability of the plant.

Big turbines selling the electric energy produced to the grid can economically profitable if the average wind speed is above 7 m/s. Turbines with smaller dimensions can be of interest from economic point of view at average speeds of 5 m/s and can be competitive compared with more expensive energy sources such as electric diesel generators.

The data presented by the manufacturer is usually indicative and calculated on the basis of a range of average wind speeds. If the wind speed is doubled, the output capacity

Phase	Costs(€/kW)	Total cost (€)	In per cents
Preliminary phase:			
Preliminary analysis	1,0	20.000	0,10 %
Terrain captation	2,0	40.000	0,20 %
Measurements, analysis	12,0	240.000	1,21 %
Total preliminary phase	15,0	300.000	1,51 %
Development :			
Designs	24,0	480.000	2,43 %
Environmental assessment and study	1,0	20.000	0,1 %
Other studies	1,0	20.000	0,1 %
Design monitoring and management	10,0	200.000	1,01 %
TOTAL DEVELOPMENT PHASE	36,0	720.000	3,64 %
Construction permit	2	40.000	0,20 %
CONSTRUCTION :			
Wind generators	695,0	13.900.000	70,34 %
Electric infrastructure of the park	70,0	1.400.000	7,08 %
Infrastructure for connection to the grid	80,0	1.600.000	8,09 %
Civil infrastructure	85,0	1.700.000	8,60 %
CONSTRUCTION TOTAL:	910,0	18.600.000	94,12 %
Engineering control and supervision	5,0	100.000	0,51 %
Total:	988,0	19.760.000	100 %

obtained increases eight times; if the wind speed is below the threshold, the wind generator is motionless and no electricity is produced.

Therefore, theoretically, the wind generator should be installed at the point with the strongest wind. Unquestionably, there are other factors that should also be taken into account:

- Infrastructure costs: the construction of adequate access roads (the components of wind generators with big capacity have very big dimensions and weight, for which respective access way is required).
- Costs for connection to the grid: they depend on the distance between the park and the grid, as well as on the type of connection cables which should correspond to the characteristics of the wind park.

Exemplary costs for a 20 MW wind park:

It should be clarified that the investments and the costs required for the commissioning of a wind park differ a lot depending on its dimensions, topographic conditions, the distance to the electric grid, the country where it is being constructed, as well as on the respective state aid (subsidy, stimulation, etc.).

Sale of energy to the grid: the energy counting mechanism

Today in the EC there is a big variety of different operative support systems that can generally be classified into four groups: premium (bonus) tariff system, green certificates, tender based system and fiscal stimuli system.

1). The premium (bonus) tariff systems (called also "feed-in" or bonus systems) exist in most of the member states. These systems are characterized by a specific price, fixed for a period of several years that should be paid by electric companies, usually distributors, to the national producers of electricity from renewable resources. The additional costs of these systems are at the account of suppliers, and the consumers are those who pay the costs in the form of a premium/bonus above the price of a kWh. The advantages of this system are: investment security and regulation possibility, as well as short term and long term technology development. The disadvantages pointed out are the possible influence on the functioning of the internal market and the risk of excessive financing. A variation of the premium tariff system is the premium mechanism or the fixed regulated prices mechanism that is currently applied in Denmark and part of Spain. With this mechanism, the government determines a fixed environmental premium or bonus to be paid above the regular price, or in the case of a free electricity market – to the renewable energy producers.

2). Green certificates are currently used in Sweden, the United Kingdom, Italy, Belgium and Poland. The electric energy produced from renewable resources is sold at the price of conventional energy. To finance the additional costs for generation of electric energy from renewable resources and to guarantee the production of the required quantities, all consumers (or - in some countries - the producers) are obliged to obtain certain number of green certificates of the companies producers of renewable energy related to a fixed percentage or share of their consumption, or total production of electricity. The financial fines for non-feasance of the above are received either in a fund for investment, development and promotion of renewable energy or the common state budget.

When the producers or the consumers wish to purchase these certificates at the lowest possible price, the renewable energy producers compete among themselves in the sale of green certificates. In this way, green certificates, if functioning correctly, can guarantee the best profitability of the investment. No doubt, with this system, technologies whose actual cost is high do not develop easily. The administrative costs with this system are quite high.

3). In two of the member states (Ireland and France) there are **tender systems** (pure bidding). France has recently transformed its system into premium system, combined with bidding in certain cases, and Ireland is also about to finish the establishing of a similar system. In a bidding procedure, the state initiates a number of tenders for supply with electricity from renewable resources, which is later supplied at the price that won in the tender procedure. The additional costs for purchasing electricity from renewable resources affect the end electric energy consumer through a specific taxation. Although, theoretically, tender systems occupy maximum market share, their restriction-expansion character does not provide for stable functioning conditions. Besides, this type of system is risky as, if the offers are low, no projects are realized.

4). Fiscal stimuli system Malta and Finland apply systems based solely on fiscal alleviations. In most of the cases (such as Cyprus, the United Kingdom and the Check Republic) this mechanism is used as an additional political element.

The classification into four groups is a rather schematic depiction of the situation. There are a number of different systems, which are a combination of mixed mechanisms, mostly combined with fiscal alleviations.

Calculation of redemption time

The redemption time is the time required for return of the investment taking into account the received income and deducting the payments made /expenses/.

Redemption time = investment: (incomes minus expenses)

The investment includes the following:

- The wind generation cost
- Cost of the construction works (infrastructure, concreting, cabling, etc.)
- Project costs (feasibility study, design and project monitoring, etc.)

After the commissioning of the wind generator, the costs related to its functioning include:

- Utilization costs (administration, terrains, insurances, etc.)

- Operation and maintenance costs (labour, spare parts, etc.)
- Taxes

Incomes related to the operation of the wind generator come from:

- Sale of electric energy
- Savings, if only part of the electric energy produced is used
- Subsidies, if applied

Based on the example given above, the installation costs amount to 19.760.000 €.

From the moment the plant starts functioning, there are incomes from selling electricity to the grid and certain operation and maintenance expenses, terrain rent, insurances, etc. As indicated in the table below, the expenses for the above mentioned wind park are as follows:

Type	Yearly costs €	In per cent
Terrain rent	19.208	2,8 %
Maintenance (labour))	37.730	5,5 %
Operation	19.890	2,9 %
Maintenance contract	308.700	45,0 %
Administration	39.790	5,8 %
Insurances	82.320	12,0 %
Spare parts replacement	123.480	18,0 %
Audits, electric power consumed, other expenses	54.880	8,0 %
TOTAL	686.000	100 %

Case studies

Case 1:

Supply with electricity and heating water. Combined plant in a country house in Pasadelo (Galicia- Spain).

The combined system consists of a wind generator and solar collectors for a country house in Vacariza. This installation supplies the necessary electric energy as well as hot water from renewable resources. The excess energy is accumulated in a set of batteries.

The decision to install a combined system for wind energy and solar energy from photovoltaic cells is determined by the need of electricity throughout the whole year. The climate in this region is quite rainy, and cloudy and windy days prevail in winter. I the summer, the wind is often zero or so weak that practically the wind generator does not work most of the time; on the other hand the sun light is sufficient for generation of electricity by the photovoltaic panels. Due to the fact that wind and solar energy complement each other, supply with electricity is maintained throughout the whole year.

Description of the system:

The photovoltaic solar system consists of 6 modules I-110/24. The photovoltaic modules are fixed to a metal construction manufactured from profile rolled steel. The dimensions of the profiles and the high quality assembly ensure the stability of the entire system.

The wind energy system consists of a rapid wind generator with nominal capacity of 1.500 W, with output voltage 48 V alternating current. It is a model with two blades located at the upwind side, i.e. meeting the wind with a passive orientation system by orientation tail. The rotor has a diameter of 2,86 m and functions at velocities of at least 3,5 m/s and up to maximum 14 m/s. As a protection measure, this turbine has automatic shut down at tilting: when the wind speed increases, its force gradually tilts the turbine backwards and slowly moves it closes and closer to the shut down point. The wind generator is installed on a metal tower at a height of 12 m.

Technical parameters of the turbine	
Model	Tilting, 1.500 W under Bornay
Material	Carbon/glass fibre
Output voltage	48 V AC
Alternator	Three phase, with constant magnets
Rotor	At the windy side, with two blades

Rotor diameter	2,86 m
Velocity range	3,5 m/s - 14 m/s
Shut down system	By tilting
Orientation system	Passive, by orientation tail
Height	12 m
Weight	42 kg

In order to prevent overloading of the accumulators, a hybrid (wind-photovoltaic) regulator from 50 to 48 V is used. This regulator limits the accumulation time and the current voltage to values that allow maintaining of the batteries in flotation condition, thus preventing their damage.

As an accumulation system are used 24 batteries, lead-acid, 900 Ah and 2 V per each element (145x206x684 mm). The batteries modules are installed inside the manoeuvre and accumulation cabin, on a wooden stand, at a height of 0,1 m from the floor.

As an alternating system a sinusoidal wave inverter is used, one phase, at 1,5 KVA.

Components used:

Item	Parameters	Units
Solar photovoltaic cells module	Model I-110/24	6
Wind generator	Tilting model 1.500 W under J. Bornay	1
Hybrid regulator	Intensity: 50 A. Voltage: 48 v	1
Sinusoidal wave inverter	Model Isoverter 1500 w / 48 v	1
Lead-acid accumulator	Model 2 AT 900 from isophoton	24

The system maintenance is simple: once a year, the condition of the electric elements, the level of the acid in the accumulators and the turbine and the panels are checked.

Case 2:

Combined (solar-wind installation) located in a rural estate on the southeast side of the mountain sierra La Ventilla, at 610 m above sea level, in the end of La Puerta de Segura (Jaén, Spain).

This installation supplies with electricity for domestic needs a rural estate and a pump of 3/4 CV for irrigation of an olive grove. The system has been in operation for about 11 years.

Description of the system:

This is an isolated system as there is no connection to the electric grid. At the moment of the installation a 50 % subsidy is granted which makes the investment competitive compared to the construction of a conventional electric grid.

The installation consists of 21 photovoltaic panels with a peak capacity of 60 W, which supply power equivalent to 1260 Wp (peak watts, e.g. the maximum power that they can supply when the sunshine conditions are optimal).

With regard to the wind system, it consists of micro turbine with nominal capacity of 250 W and functions with output voltage of 24 V DC. The chosen model is a micro turbine at the windy side, with three blades and no brake system. In this case the turbine can resist winds with speed up to 60 m/s (216 km/h), called survival speed. Speeds above this one represent a risk to the integrity of the installation; this speed is practically above the 12-th degree on the Beaufort scale and the probability for such a speed is negligible.

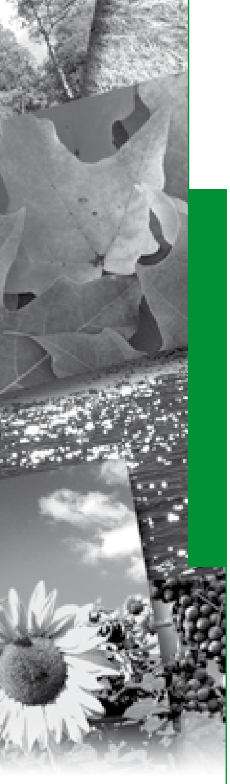
Technical parameters of the turbine	
Model	Acsa-Lmw-250
Material	Polyester or epoxy resin, reinforced with glass fibre
Output voltage	24 V AC
Alternator	Three phase, with constant magnets
Rotor	At the windy side, with three blades
Diameter of the rotor	1,7 m
Speed range	3 m/s - 60 m/s
Brakes system	NA
Orientation system	Passive, with orientation tail
Height	12 m

In this case the voltage load is 24 V. The lighting of the house is performed with 24 V DC; the rest of the domestic electric appliances and the equipment function with 220 V alternating current.

Components used:

ITEMS	PARAMETERS	Q-TY
Solar photovoltaic panels	Individual capacity : 60 Wp	21
Wind generator	Model Acsa-Lmw-250 Alternator type – three phase	1
Hybrid regulator	Current intensity: 50 A. Voltage 24 V	1
Inverter of sinusoidal wave	Model Smart Guard Pro SGPIII 2000 1300 W	1
Lead-acid accumulator	Model TXE 1200 from Fulmen	12

The owner claims that he is satisfied with the system, which for the 11 years of its functioning has left him only 3 days without electricity. The entire electric equipment of the installation has functioned without failure. The first batteries installed have endured 7 years.



MICRO HYDRO POWER

Introduction

Aims

This guide aims to give an overview of micro hydro technology and its implementation in the United Kingdom. Included are guidelines for how to carry out calculations of hydropower potential and make estimates of revenue from electricity sales. Advice is given regarding scheme implementation including scheme layouts, equipment, connecting to the grid, legal issues and likely costs. Environmental benefits are quantified and a number of recently developed sites are described as case study examples. Contact information is given for all relevant organisations mentioned.

Scope

The scope of this guide can be broadly summarised as follows:

- UK focus but most elements of implementation methods and equipment are common to other European countries
- Micro hydro only (therefore power outputs of less than 100 kWe)
- A general technical readership is assumed without necessarily having detailed knowledge of the technology. It is anticipated that a high proportion of readers may be non-native English speakers. Hence illustrations and table formats have been widely used.
- The emphasis is on the current status of technology and recent innovations
- A strong practical bias to the content seeks to reflect the developers perspective

Micro hydropower and its benefits

Micro hydro refers to hydro power systems with an electrical power rating of 100 kW or less. A 100 kW system will produce 100 standard units of electricity in one hour. Micro hydro systems differ from large hydro power since the flows of water required are much smaller. This has the advantage that the potential number of suitable sites is very large in a country with many streams and rivers. Most of these sites have been overlooked in previous resource studies carried out in the UK (and in other European countries) and therefore this scale of development is worthy of particular attention.

During the first half of the 20th Century a considerable number of former watermills where converted to produce electricity using turbines and DC generators (see Case Study on Shawford Mill. This provided a localised supply often to nearby houses and was mainly used for lighting. For the most part these then fell into disuse with the spread of the national grid across most of the country and the adoption of AC electricity as the supply standard. Increasing interest in renewable energy and decentralisation of the power network are encouraging this largely forgotten technology to be revisited.

The considerable benefits of micro hydro power include the following:

- A consistent and reliable source of power where suitable sites exist
- Different to large hydro since environmental impacts of installation are negligible.
- Renewable energy source therefore helping to reduce greenhouse gas emissions and having a net positive impact on the environment.
- Constant generation over long periods without the intermittency of wind and solar power
- Good correlation with demand (more hydro energy is available in winter when energy demands in the UK and Northern Europe are highest)
- Long lifetime of systems, typically at least 30 years before major refurbishment
- Low maintenance requirements and running costs
- Reasonable payback for grid-connected systems, often 10 years or less
- A well established technology
- Benefits for rural areas (employment, income, tourist interest, maintenance of waterways)

The potential resource and challenges for developers

There is considerable potential for micro hydro electricity in the UK. There are two types of sites which are particularly worthy of consideration for development:

1. Historic water mills

Water was once used extensively as a source of motive power in the British Isles. Some estimates put the number of old mill sites in the UK as high as 20,000. Government targets for renewable energy and the development of modern, small-scale turbine units now make re-activation of many of these old sites for electricity generation economically worthwhile. A major advantage of these sites is that it is often possible to reuse some of the existing civil structures such as the weir and the leat, thereby reducing the cost of the installation. Turbines which were installed to drive DC generators can also be found at a surprising number of sites. These can often be refurbished and the electrical system only replaced which make particularly attractive developments.

2. Hilly areas with spring-fed streams

In addition to historic sites, considerable potential exists in many hilly areas of Britain for micro hydro power. Turbines are available which can utilise quite small spring fed streams for power generation if the fall is sufficient. These sites can often be developed at reasonable cost since civil structures associated with large flows of water, such as weirs, are not required.

3. Other sites

Many of the remaining weirs and sluices, elements of the water supply infrastructure, canals and locks and even flood defences can provide opportunities for worthwhile micro-hydro development.

Until recently, there have been a number of impediments to the development of hydro sites below 100 kW for electricity generation in the UK. These were:

- Cost and complexity of grid connection discouraged small generators
- Low prices paid for electricity produced from small renewable generators
- Lack of government grants for subsidising the capital cost of renewable energy systems
- Prohibitively expensive turbine and generator units

This situation is now changing. Concerns about climate change and fuel security is encouraging greater interest in small, decentralised renewable energy systems. Small-scale hydro power, once used extensively and very successfully in the UK to provide a reliable source of industrial motive power, is the most cost-effective of all the renewable resources where suitable sites exist.

Guidelines for small generators have now been established, with greater simplification of grid-connection methods for generator outputs below 11kW. Electricity supply companies are now obliged to buy a certain proportion of their electricity from renewable sources, such as hydro power. This is administered through the Renewable Obligations scheme and ensures higher prices are paid for registered generators. Government grants have become available for domestic and community renewable power projects under the DTI's 'Clear Skies' initiative.

Identification of suitable sites and equipment

Hydropower basics

Power is measured in watts or kilowatts. 1kW = 1000W. Hydro power depends on two factors which vary from site to site. These are the flow of water and the head through which it falls.

Calculation of hydropower

The hydro power in a stream or river can be calculated as follows:

$$\text{Hydro Power (Watts)} = \text{Head (m)} \times \text{Flow (m}^3\text{/s)} \times 9.81^* \times 1000$$

(*9.81 is acceleration due to gravity which can be assumed to be constant and 1000 is approximate density of water). For example, if the available flow is 0.15 cubic metres per second (150 litres per second) and the net head is 4.7 metres, the hydro power potential is

$$4.7 \times 0.15 \times 9.81 \times 1000 = 6{,}916 \text{ W or } 6.9 \text{ kW}$$

To estimate the electrical power produced by a generator, the efficiency of the system must be taken into consideration. Efficiency is the word used to describe how well the power is converted from one form to another. A turbine that has an efficiency of 70% will convert 70% of the hydraulic power into mechanical power (30% being lost). The system efficiency is the combined efficiency of all the processes together. The system efficiency for electricity generation using micro hydro is typically between 50% and 70%. It is easier to achieve higher efficiencies as the systems increase in size. Therefore the smallest micro hydropower system will typically have the lowest system efficiencies.

Electrical Power = Hydro Power x System Efficiency

i.e. as a rough estimate, if there is found to be 6.8 kW of hydro power in a small river, the electrical power is

$$6.9 \times 50\% = 6.9 \times 0.5 = 3.45 \text{ kW}$$

Flow: The amount of water flowing is measured in cubic meters per second or litres per second for small flows. 1 m^3/s = 1000 l/s.

Head: The head is the vertical distance through which the water falls and is always measured in metres. Hydro sites can be categorised according to the available head. For example low head sites have heads of 10 metres or less and high head sites have heads of 20 metres or more. When calculation hydropower potential it is important to consider the head loss which will occur as a result of turbulence and friction as the water passes through the hydropower system. This reduces the measured or gross head to give the net head used in the example calculation on page 2.

Resource assessment

Accurate measurement of head and flow are necessary to estimate the power potential at a site.

Head measurement

There are various methods of measuring the available head. For low head sites the most accurate method is using a surveyor's level and measuring staff. Identification of bench mark levels in the vicinity enables the measurements taken across the time to be tied in to Ordnance datum levels. Reference can then be made to levels AOD (Above Ordnance Datum) which is particularly important for assessing the flooding potential at a site and enable the plans to be viewed in conjunction with flood maps for risk assessment by the Environment Agency (see Land Drainage Consent)

At sites where the head is more than 25 m, a digital altimeter allows more rapid estimates. Other methods include the Abney Level and nowadays handheld GPS (Global Positioning Systems) which are now often accurate to within a few meters and can be used for approximate survey and rapid appraisal of higher head sites.

Flow assessment

The flow rate at a particular site is determined by the interaction of a number of factors including the size of the catchment area, the local rainfall, the rate of evaporation and the geology of the area.

The flow rates in all major UK rivers are measured continuously at Environment Agency gauging stations. This flow data can be obtained free of charge by contacting the Agency with details of the location. Measurements are usually taken at 15 minute intervals but daily averages (mean daily flows) are sufficiently detailed for hydropower resource assessment. A typical example of flow gauging data recorded on a river in Somerset, UK over a single year is shown in Figure 2-1.

In order to characterise the flow variation for resource assessment, long term flow data is usually presented in order of magnitude on a Flow Duration Curve. This shows the percentage of time which a particular flow rate is likely to be exceeded in any given year. A typical flow duration curve is illustrated in Figure 2-2.

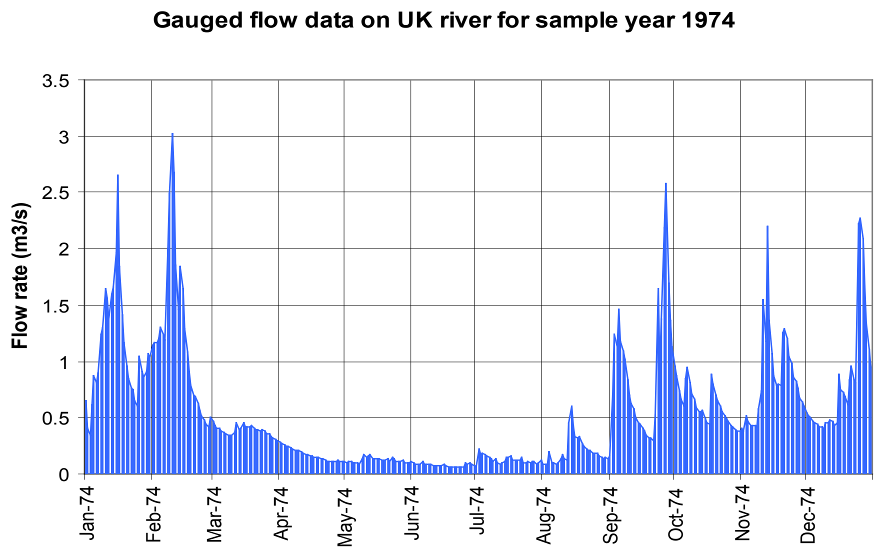
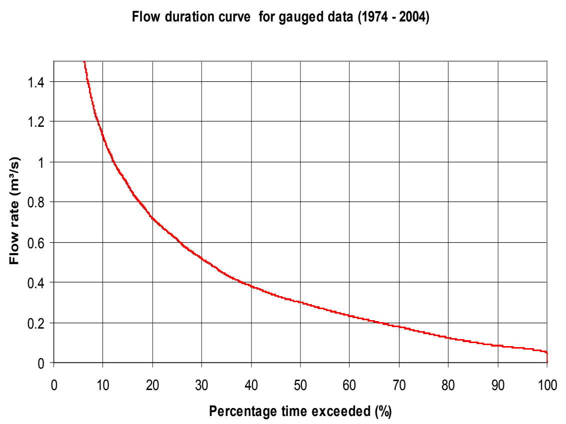


Figure 2-1 Gauged river flow over a 12 month period (River Brue)



Percentage Exceedence	Flow Rate (m^3/s)
Q10	1.069
Q20	0.685
Q30	0.495
Q40	0.364
Q50	0.285
Q90	0.079
Q95	0.067
Qmean = Q31.6	0.474

Figure 2-2 Flow duration curve produced using long term flow data with summary values (Table 2-1)

Flow duration curves which are quite flat in appearance characterise flows which are heavily spring fed. Curves which slope more sharply are typical of sites where the flow rate is mainly influenced by rainfall run-off. In general, a small micro hydropower scheme in the UK, sized for maximum annual electricity generation, will not be expected to have sufficient water to run continuously throughout the summer months.

Often the nearest gauging station is a considerable distance from the site of interest and some form of correction is required to allow for the differences in catchment area. The simplest method is to compare the ratio of the catchment areas between the gauging station and the site. It should be possible to trace the overlapping catchment areas from an Ordnance survey map and then use squared paper to estimate the area. The ratio of areas will give a factor which can be applied to the gauging station data to 'correct' it to the site.

Catchment modelling and flow prediction at un-gauged sites can be achieved more rapidly and accurately using computer programs such as Low Flow 2000. These can also be used to produce more accurate correction factors for adjusting long term gauged data provided by the Environment Agency.

Micro hydro scheme layouts

Low head projects

Three typical layouts for a 'low-head' micro-hydro scheme at a former mill are illustrated in Figure 2-3. Since low head micro hydro schemes are generally characterised by substantial design flow rates, use is often made of exiting infrastructure such as weirs, leats and sluices. This helps to prevent excessive civil building costs which can easily undermine the viability of a project.

Siting of the turbine-generator unit will depend on the available resource and the suitability and cost of using existing structures as part of the scheme.

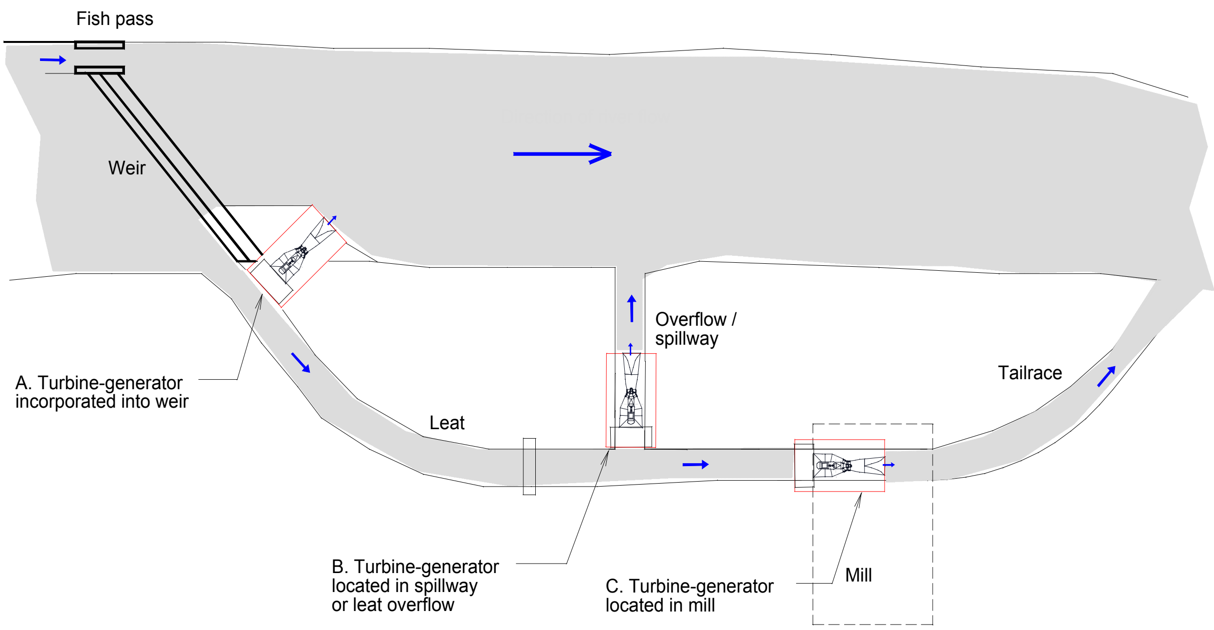


Figure 2-3 Layout possibilities of a turbine-generator located at a former mill

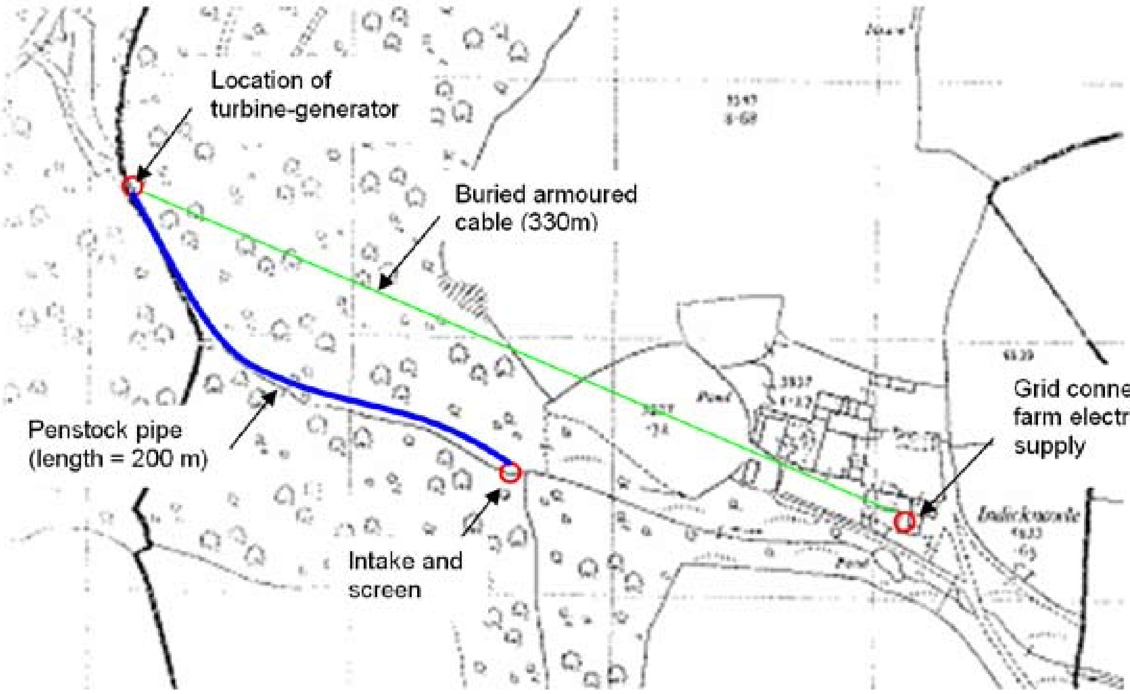


Figure 2-4 Typical layout of a high-head micro hydro scheme supplying power to nearby farm buildings

A. At a site where the leat has been filled in or there are concerns about flood risk to nearby property, incorporation of the generating equipment across the weir may be the only viable solution. Equipment such as the 'siphonic propeller turbine' have been specifically designed with this type of application in mind.

B. Nowadays, mill buildings are often redeveloped as living accommodation. If the leat remains clear, siting a turbine at a sluice gate or spillway may the most cost-effective development by using the leat to increase the power output of the system.

C. The wheel pit (found inside or next to the mill building) usually provide the best location for a new hydropower development, particularly if the original wheel has been removed as this is where the available head is likely to be greatest and building work can be minimised (see Case Studies on Gants Mil and Lemsford Mill.

Higher head projects

The layout of a 'high-head' micro hydro scheme which can be developed in a cost-effective manner will look quite different to the low head schemes which maybe viable at former watermills.

At these sites much smaller flow rates may be used if sufficient head can be gathered. This is achieved by using a penstock pipe to deliver a pressurised jet of water to the turbine. The lower flow rates enable the size of the turbine unit and the intake structure to be scaled down considerably. The use of plastic mains water pipe can enable the cost of the penstock pipe to be maintained within reasonable limits even if considerable lengths are required. A typical scheme layout is illustrated in Figure 2-4.

The intake is situated at the confluence of two streams in a wooded valley. A 200 metre long penstock pipe gathers 40 metres of head (approximately 4 bar of pressure) and connects to a small impulse turbine further down the valley. A buried armoured cable supplies power to the farm buildings with surplus power being exported to the grid via the single phase transformer located nearby.

Due the highly spring-fed nature of the streams, removal of water-borne debris from the intake screen is much less of an issue than at lower head sites with higher flow rates. The higher head also enables self-cleaning screens to be used such as the 'Coanda Aquashear' reducing the maintenance requirements to a minimum.

Hydro generation systems

Conventional turbine technology, much of which was developed during the first half of the 20th Century, is now being supplemented by innovative and lower cost designs. This is enabling re-evaluation of many sites, previously considered to have been of marginal viability only. The system selected will principally depend on the head and flow range at the site and the available budget. Eight turbine-generator designs have been reviewed all which have recently been installed or planned for installation at micro hydro sites around the UK.

Intake screens

In order for a micro hydro system to function correctly an intake is required which will divert sufficient water to the turbine. A correctly designed intake will ensure that the

Turbine-generator designs

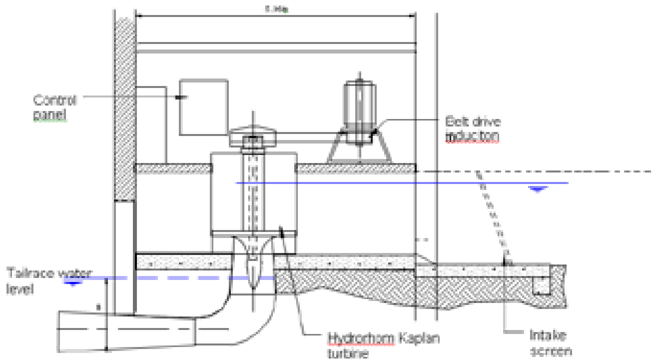
Turbine type:	Kaplan (Hydrohrom, Czech Republic)
Key features:	Designed for low head, high flow sites, (H = 1 to 3 m, Q = > 0.7 m³/s)
Advantages:	Can operate over a range of flows and maintain high efficiency
Drawbacks:	High capital and installation costs
	

Figure 2-5 Hydrohrom Kaplan under installation and section through vertical axis Kaplan (right)

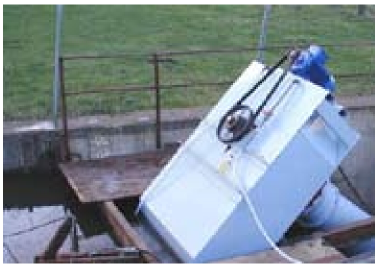
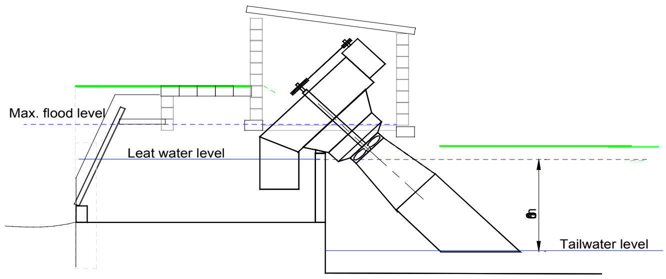
Turbine type:	Siphon propeller (Derwent Hydroelectric Power Ltd, UK)
Key features:	Designed for low head, high flow sites, (H = 1 to 3 m, Q = > 0.7 m³/s)
Advantages:	Very cost-effective design as enables civil building costs to be minimised
Drawbacks:	Lower efficiency than fully regulated Kaplan turbine as turbine geometry is fixed. Limited flow range. Not yet widely proven
	

Figure 2-6 15 kW Siphonic propeller turbine and section through installation (right)

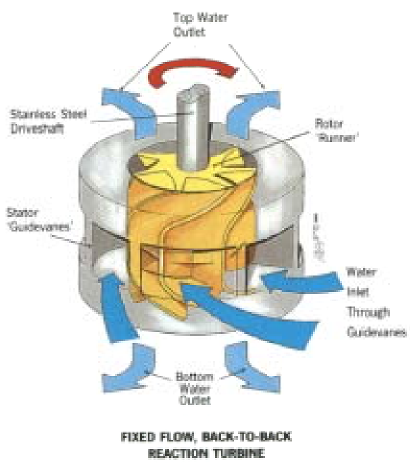
Turbine type:	Overshot waterwheel (HydroWatt GmbH, Germany)
Key features:	Designed for low head, high flow sites, (H = 1 to 5 m, Q = > 0.1 m³/s)
Advantages:	Maintain efficiency over a range of flows, building costs may be much lower at some mill sites where the new installation replaces former wheel, considerable aesthetic benefits as visually and architecturally interesting. A narrow screen is not required with overshot wheels as debris is thrown clear
Drawbacks:	Fairly high cost capital, lower efficiency than a fully regulated Kaplan turbine.

Figure 2-7 Overshot waterwheel with 10 kW grid-connected generator (HydroWatt GmbH)

Turbine type:	Low cost propeller (Powerpal, Vietnam / Canada)
Key features:	Designed for low head sites (H = 1.5 m, Q = > 0.15 m³/s) Widely used for battery charging in rural parts of SE Asia
Advantages:	Exceptionally low cost due to large scale manufacture in Asia
Drawbacks:	Low efficiency and limited lifespan, required some modification to connect a grid-linked induction generator instead of the permanent magnet alternator shown.

Figure 2-8 Low cost propeller turbine designed for battery charging and widely used in S. E. Asia.

Turbine type:	Modular polymer turbine (Hydro Generation Ltd, UK)
Key features:	Designed for medium and low head (H = 1 to 10 m) flow range between 0.1 and 0.5 m³/s depending on diameter selected.
Advantages:	Medium to low capital and installation cost
Drawbacks:	Fixed flow only at present as fixed speed and turbine geometry. Not yet widely proven.



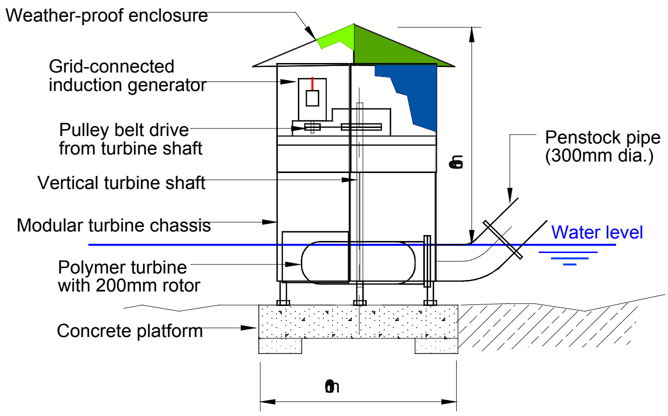
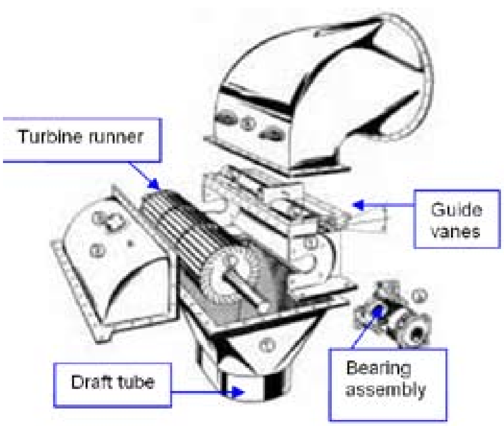


Figure 2-9 Innovative polymer turbine runner and guide vanes (left) with installation sketch (right)

Turbine type:	Crossflow turbine (Ossberger GmbH, Germany)
Key features:	Can be built to operate over a wide range of site conditions
Advantages:	High efficiency is maintained over wide flow range with twin guide vane designs. May be located above flood level using a draft tube. Will allow small debris (leaves etc) to pass without clogging.
Drawbacks:	Capital and installation costs may be high



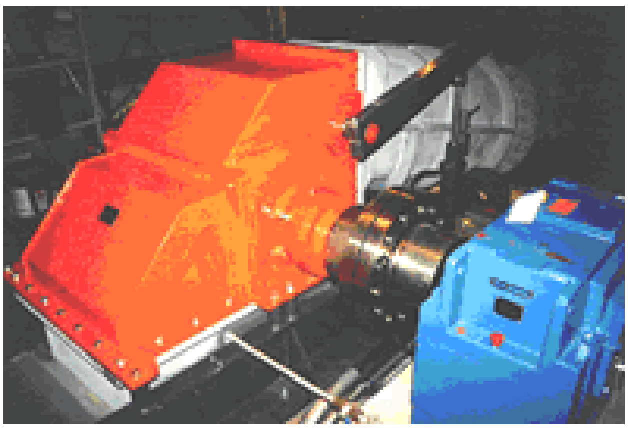


Figure 2-10 Ossberger crossflow turbine components (left) and installation (right)

Turbine type:	Turgo (Gilbert, Gilkes & Gordon Ltd.)
Key features:	Designed for medium and head sites with wide flow ranges (H = 20 to 80 m, Q = > 0.02 m³/s)
Advantages:	Can operate over a wide range of flows and maintain high efficiency. May be built to very high specification and have long lifespan with little maintenance (>50 years before refurbishment)
Drawbacks:	Very high capital costs for fully regulated designs

Figure 2-11 Gilkes Turgo turbine with two regulated spear valves

Turbine type:	Pelton turbine
Key features:	Designed for medium to high head and lower flow rates. Flow rates can be increased by adding up to 4 nozzles (H = >25 m, Q = > 0.01 m³/s)
Advantages:	Can operate over a range of flows and maintain high efficiency. Careful turbine sizing can enable direct coupling with an induction generator resulting in a very cost-effective system (see picture). Small Pelton turbines with automatic flow regulation are starting to become available in the UK at competitive prices.
Drawbacks:	Require a head in excess of 25 meters and maximum flows are limited.

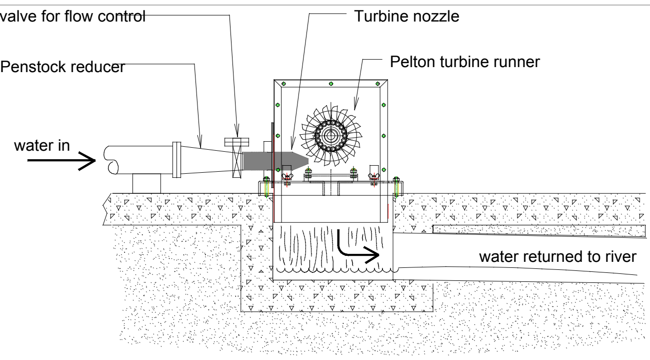


Figure 2-12 Small Pelton turbine under installation (left) and section though (right)

penstock pipe remains full under varying river flow conditions and prevent ingress of larger debris which could clog or damage the turbine.

Figure 2-13 Ossberger automatic screen cleaner

Intake screen cleaning is by far the largest maintenance issue with run of river hydropower schemes particularly during the autumn months in the UK and Northern Europe. Despite lower flow rates associated with micro hydro systems screen, cleaning is still a daily chore at many sites. Significant improvements in energy output are possible if adequate consideration is given to this at the outset.

An automatic screen cleaner can detect when the screen is becoming blocked and use a hydraulic or electrically actuated arm to clear debris. A flushing channel may also be incorporated to return debris to the river, downstream of the intake.

An automatic cleaning system manufactured by Ossberger of Germany is shown in Figure 2-13. Alternative designs that use a chain-driven mechanism instead of an arm are available which have a lower maximum height. The systems sometimes must be shrouded from view due to planning or listed building requirements.

Figure 2-14 Coanda self-cleaning intake screen

The Coanda Aquashear screens (available from Dulas Ltd.) are self-cleaning under most conditions and exclude all silt and debris greater than 1mm diameter, eliminating the associated operational costs of erosion damage and blockage to pipes and machinery, whilst increasing revenue by maximising flow availability. The water flows over the top of the screen and is drawn through the wedge-shaped bars to fill a pipe intake incorporated into the base. A Coanda screen under installation is illustrated in Figure 2-14.

Control and grid-connection equipment

Automatic turbine regulation was once performed exclusively by mechanical governors and hydraulically-actuated valve control systems. These are still used on larger hydro due to their inherent reliability but are often not cost-effective for micro-sized systems. In addition to innovations in turbine manufacture new, lower cost electronic control systems are now available and much less expensive than their traditional counterparts. Furthermore, in most cases they are proving that they also can be relied upon in equal measure.

A signal from a water level sensor at the turbine intake is used to switch an actuation circuit with often with robust DC motors as the prime mover. These can control the position of valves, sluice gates and guide vanes in order to modify turbine operating flows under varying river conditions and enable both the operating range and efficiency to be maximised. Maximising the output is just as important for small, grid-connected schemes when every unit of renewable electricity generated is highly valued for export often in order to meet lengthy payback targets or to offset local energy demand. A DC drive has the particular benefit that motors may easily be driven by batteries to close down the flow and prevent prolonged over-speed should a fault occur of the grid become unavailable. Automatic start-up is then possible when the fault is rectified or mains power returns.

A mains connection unit is required to ensure that the generator is only allowed to operate during favourable conditions and is automatically isolated in order to prevent 'islanded' operation if the grid fails. The grid connection circuits are usually combined with the valve control systems in a single unit. The specification which the grid connection system must adhere to is determined by the UK Government through the Electricity Supply Act. Local distribution network connection requirements for small generators which have a rated output of more than 16 Amps per phase (3.7 kW single phase or 11 kW 3-phase) are usually required to adhere to the Electricity Association's Engineering Recommendation G59/1. Electrical generators with a power output of less than 16 amps per phase qualify for connection following the Government's new statutory guidelines known as G83. This is an attempt to reduce the regulation and expense for grid-connection of the smallest systems as systems installed under the G83 guidelines do not require network analysis or witness testing by the Distribution Network Operator.

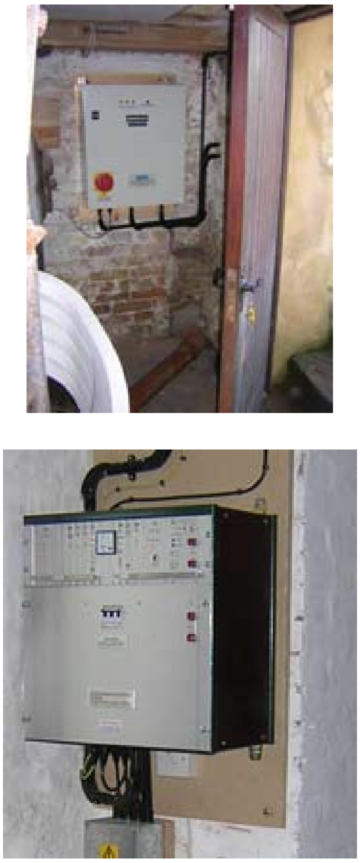


Figure 2-15 G59/1 'Mini-mainscon' grid connection unit from GP Electronics (left) and G83 grid connection unit from Sustainable Control System (right) both installed by Hydro Generation Ltd on micro hydro schemes in Somerset, UK

Off-grid systems may still use manual flow regulation as they are often sized to run for much of the year at full output. A control system is still required in order to maintain constant voltage and frequency under changing user loads. This is achieved by a generator control system which diverts excess power to a ballast load thereby keeping a constant load on the generator.

Legal requirements

Abstraction License

Most hydro sites require an abstraction licence from the Environment Agency (EA) for the right to divert water to a turbine. Once operational, no charge is made for the abstracted water for hydro installations up to 5 MW output. No actual abstraction takes place since 100% of the water is returned to the river, however, the licensing process enables the EA to monitor water usage and to prevent the interests of the local ecology or other water users from being compromised.

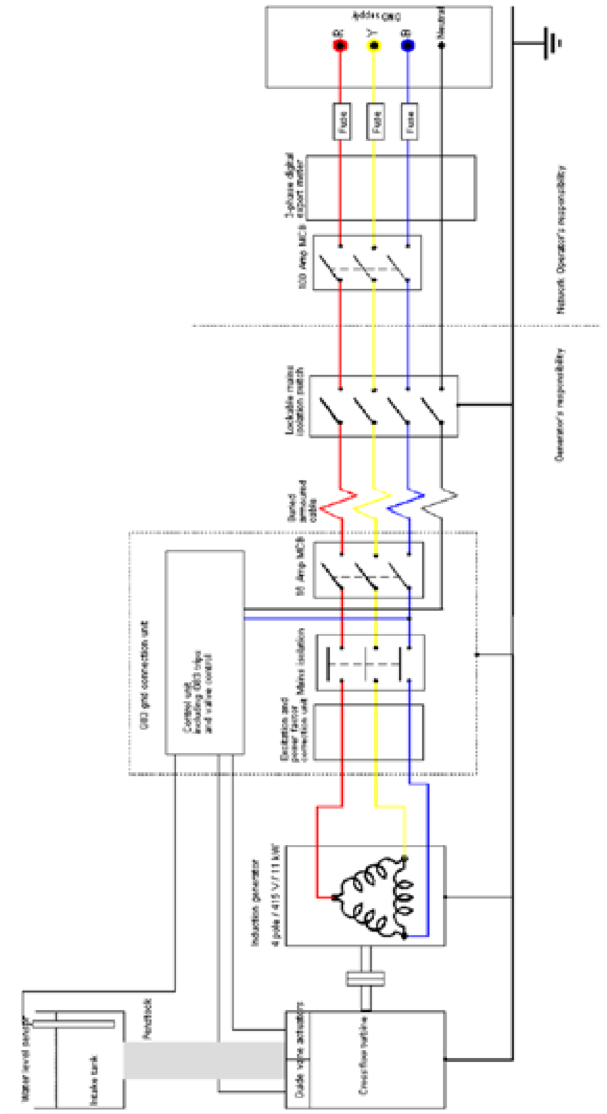


Figure 2-16 Block diagram of typical electrical system for a 3-phase G83 grid-connected generator

The ease with which a license from the EA can be obtained depends significantly on the watercourse in question and on the particular office which has responsibility for the affected catchment. Guidelines exist for the Agency staff but little experience has been gained in many parts of the country by cur rent water licensing officers since, until recently, abstraction license requests for hydropower developments were few and far between. The guidelines state that the complexity of the environmental assessments required should be in proportion to the scale of the development which is proposed. In practice however, many abstraction license applications get somewhat bogged down as they are passed between the various departments (fisheries, ecology, water licensing etc) and the process can easily become protracted over several months.

Of particular note for discussion will be the maximum abstraction rates, method of turbine regulation and provision of compensation flow to any depleted sections of the river. Rivers which are migratory routes for salmon and salmanoid fish species will require substantial compensation flows during spawning periods. It is wise to clarify the terms of the abstraction license before any investment is committed towards hydropower equipment as the viability of the scheme may be significantly affected. Once the application has been agreed in principle, a statutory advertising process is followed and the application is made available to the public so that local concerns can be registered.

Land Drainage Consent

All new building work within 8 metres of a main river or any new obstruction in the flow of an ordinary watercourse (such as a leat) requires Land Drainage Consent from the Development Control office of the EA. The main purpose is to prevent flooding and protect environmental interests. The process for obtaining the Land Drainage Consent involves submission of an application form with engineering drawings and design calculations for the proposed works, whether temporary, such as coffer dams, or permanent structures. Providing there is no increased flood risk and that a sound engineering basis behind the proposed works can be demonstrated, then generally applications should not be refused.

Planning Consent

Construction of new turbine houses will almost certainly need planning permission from the local authority. Any new building or modification to an existing building that requires planning permission and is on a watercourse will involve consultation with the EA in the planning process. In most cases the Environment Agency will only give their consent to the planning application after a Land Drainage Consent application has been approved.

Listed Buildings Consent

For any sites with listed buildings a Listed Building Consent application will need to be made for all works within the 'curtilage' of the mill. Curtilage can be broadly defined as the area surrounding the mill that is historically or architecturally connected to the building; it is often the land boundary of the property, but can also include a neighbours land in exceptional circumstances. Generally speaking, conservation officers view the re-activation of historic water mills positively provided that disturbance to historic fabric is minimised and where necessary is carried out in a sympathetic way.

Financial viability of micro hydropower

Typical scheme costs

A typical cost breakdown for a micro hydro scheme implemented in a watermill is illustrated in Figure 4-1. The costs given are indicative rather than actual.

This cost breakdown makes the following important assumptions:

- 5 metres gross head is available in the wheel pit of the mill (waterwheel removed)
- Minor building work only is required to adapt the existing intake and no turbine enclosure is necessary.
- The design flow rate is 500 litres per second giving 12 kW peak power output
- A budget priced crossflow turbine is installed with and electronic rather than hydraulic flow control system.
- No upgrading of the transformer to which the generator connects is required and the cables provided by the DNO (Distribution Network Operator) are installed on a 'self-dig' basis
- The site owner assists with the installation to reduce costs.

For sites with lower heads, the building costs are likely to increase rapidly as civil structures are required to locate the turbine and manage correspondingly greater flow rates. For high head sites where small impulse turbines can be used, the penstock costs will increase but this may be offset by lower cost turbine-generator units in some cases. The penstock cost will ultimately be highly dependant on the pipe length required and the design flow rates.

Export of renewable electricity

Electricity supply companies are required to purchase a proportion of their electricity from renewable sources under the Government's Renewables Obligation programme. This guarantees that a premium price is paid to registered renewable generators and is design to encourage greater investment in this sector. A survey of prices paid for exported power by UK electricity companies has been conducted. The results are summarised in Table 4-1.

Other Electricity supply companies which were contacted but not offering a export agreement for small generators at present included Ecotricity, Npower, Scottish Power, and PowerGen.

In addition to the flat price paid as indicated above, the generator is also awarded Renewable Obligation Certificates (ROCs). The number of ROCs awarded is calculated from the amount of energy produced by the system over a year. These can then be traded on the electricity market once the generator has registered with the regulator OFGEM. The registration and subsequent trading of ROCs can all be handled by a third party such as Tradelink Solutions. They are currently offering £32 - £35 per ROC (one ROC awarded per 1 MWh or 1000 kWh). They can also provide a registration service with the regulator for a one-off fee of £85.

The results show that a micro hydro generator could be paid up to 8.5 pence per unit of electricity exported (assuming a export agreement with EDF Energy plc and ROCs sold to Tradelink solutions). If all of the electricity is consumed on site and the full domestic tariff is paid (currently around 8 pence per kilowatt hour) then the effective value of each unit generated increases since ROCs can claimed regardless of whether the power generated is exported providing that a separate meter is installed to record the total generator output.

Estimating potential revenue and payback

Annual energy capture is the term used to describe the

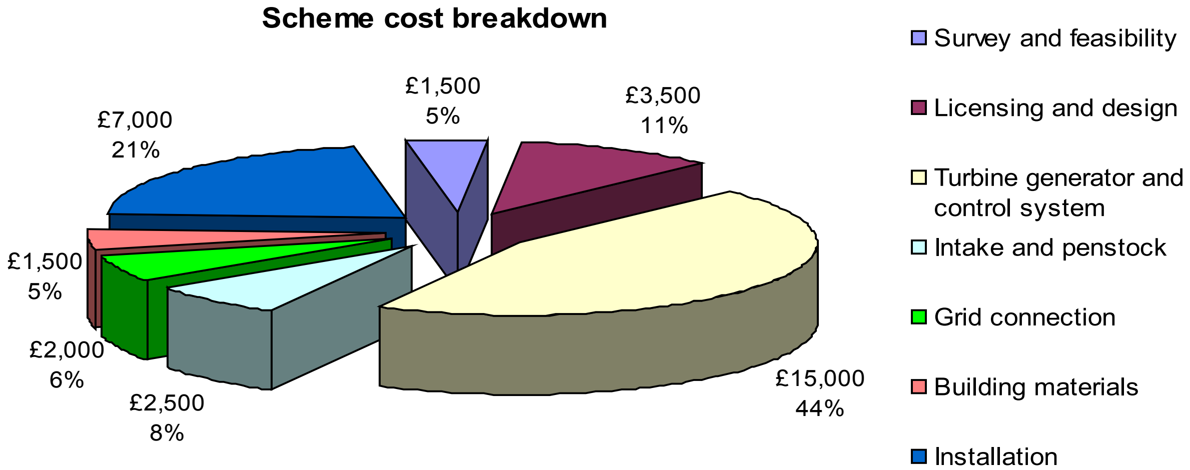


Figure 4-1 typical cost breakdown for a micro hydro scheme installed in a UK water mill

total number of electricity units which can be generated at one site over a year. An estimate of the annual energy capture can be made once the turbine and generator have been approximately sized.

Assuming a turbine and generator is installed which will produce 10 kW at rated output, the electricity units generated throughout the year in kilowatt hours can be estimated by multiplying by the number of hours in the year (24 x 365 = 8760) and a capacity factor to allow for the fact that the flow for rated output will not be available all the time. A capacity factor (CP) based on a typical flow variation for a UK river is between 0.4 and 0.5. Assuming a capacity factor of 0.45 the annual energy capture will be:

	Electricity company	Price paid for power exported (£ / kWh)	ROC included in price paid?	Require supply agreement?	Geographical restriction / other charges
1	EDF Energy plc	0.05	No	Yes	Not restricted / no standing charge
2	Green Energy UK Ltd	0.03	No (additional £0.03 / kWh towards ROC)	No	Not restricted / Standing charge of 15 pence per day (£54.75 p.a.)
3	Good Energy Ltd	0.038	No (additional £0.03 /kWh towards ROC)	Yes	Not restricted / no standing charge
4	Scottish & Southern Energy plc	0.06 – 0.07	Yes	Yes	Not offering an export tariff in areas where they are not the network operators unless half hourly metered.
5	Tradelink Solutions Ltd	------	£0.032 – 0.035	No	Additional 5% of buy-out price charged

Table 4-1 Survey of export prices offered to small renewable generators (January 2006)

Annual Energy Capture

= Power Output at Rated Flow x 8760 hours x CP

= 10kW x 8760 hours x 0.45

= 39,420 kWh

Computer programs can be used to determine the likely energy capture with a greater degree of accuracy. The results from a program illustrated below also calculate the abstraction volumes with a particular turbine design and take into account the turbine-generator efficiency curve at different flow rates. The energy capture prediction is based on the actual flow data which can be provided by the Environment Agency and corrected to the site in question. This enable very rapid and accurate appraisal of turbine options to enable the design to be optimised.

Quantifying the benefits

In addition to projected income from power exported or power purchase offset, it is often useful to quantify the

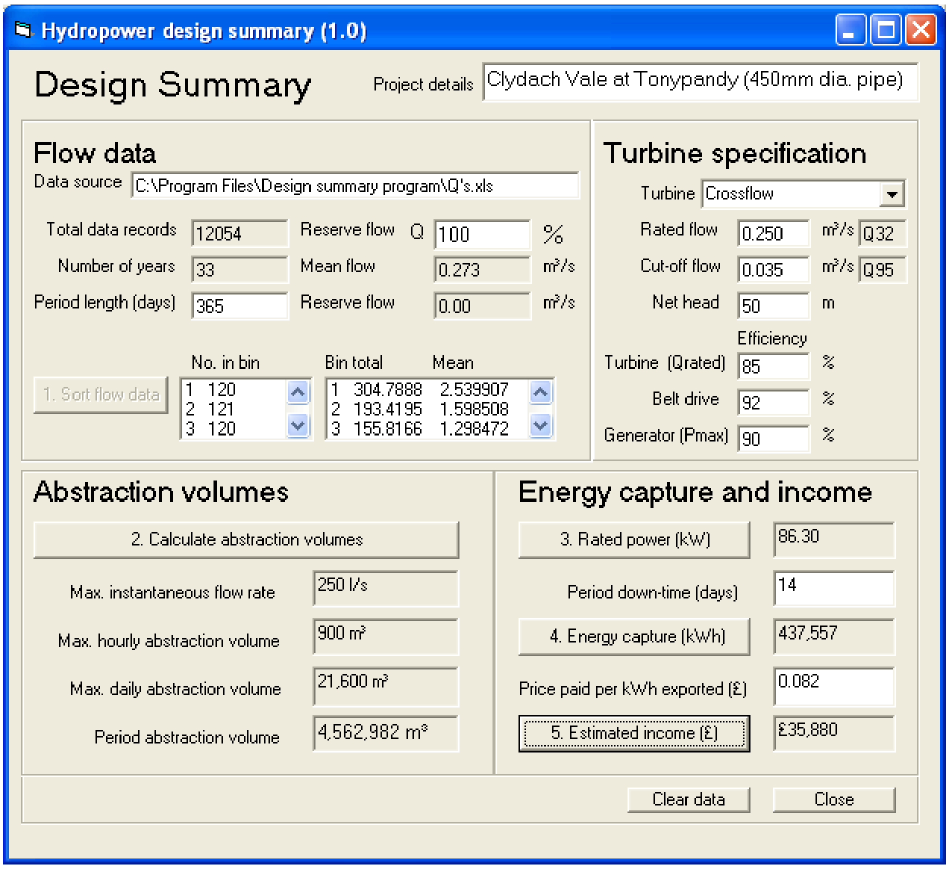


Figure 4-2 Software enabling rapid site appraisal using detailed flow data with various turbine options (Pico Energy Ltd)

benefits of renewable energy schemes in other ways. This can help to reinforce the merit of a project to potential funders and site owners.

Micro hydro schemes even with low headline power outputs can often deliver significant quantities of renewable electricity to the grid over the course of a year, particularly compared with other renewable options of comparable size.

Useful methods for evaluating the benefits of a particular scheme in addition to the direct income through electricity sales are

a) The number UK homes which would have their average electricity needs met by the scheme. The daily electricity consumption of a modern UK family home is approximately 12 kilowatt-hours. This equates to an annual per household demand of 4,380 kWh.

b) The quantity of carbon dioxide emissions offset assuming that the electricity would otherwise have been produced by conventional fossil fuel-fired power stations. A modern coal-fired power station produces approximately 0.46 kg of CO2 per kilowatt-hour of electricity generated.

Case studies

Case study 1	Gants Mill
Site Location	Bruton, Somerset, OS Grid Ref. ST 674 342
Turbine Manufacturer	Valley Hydro Turbines Ltd, Cornwall
Installer	Hydro Generation Ltd, Devon
Design conditions	Gross Head = 5.0 m Design flow rate = 0.500 m^3/s
Hydropower system	Twin guide vane crossflow turbine
Generator	15 kW asynchronous, 3-phase, 1000rpm
Control system	Supplied by GP Electronics Ltd, Devon. Water level sensor to geared DC actuator motors and G59/1 grid connection unit with power factor correction, voltage and frequency trips
Energy Capture	Approx. 50,000 kWh per year
Project background	 *Figure 6-1 Gants Mill, Bruton, Somerset* Gants Mill in the Mendip Hills area of Somerset dates back to the 12th Century. Over the years it has served a variety of purposes including corn mill, fulling mill and silk mill. A weir diverts water from the River Brue along a leat some 500 meters in length to the mill where a head of approximately 5 meters is gained. Once it has passed through the mill building, the flow is returned to the river via a brick lined tailrace tunnel which runs underground for approximately 100 meters. If the leat flow is in excess to the requirements, a bypass sluice with overflow enables water to be returned to the river just upstream of the mill and prevent the leat banks from being breached. The original waterwheel was removed during the early 19th Century and replaced with an Armfield turbine to enable the mill machinery to continue to be operated. The mill owner, Brian Shingler, continues to use the historic turbine to grid barley and feed his sheep. However sufficient area remained in the old wheel pit to accommodate a modern turbine-generator system and, in 2003, the Mill underwent transformation once again to enable the production of electricity. A crossflow turbine from Valley Hydro Turbines Ltd in Cornwall was installed and connected to a grid connected induction generator system designed by GP Electronics Ltd from Devon. Installation was carried out by another local company Hydro Generation Ltd, also based in Devon.

Scheme design and operation

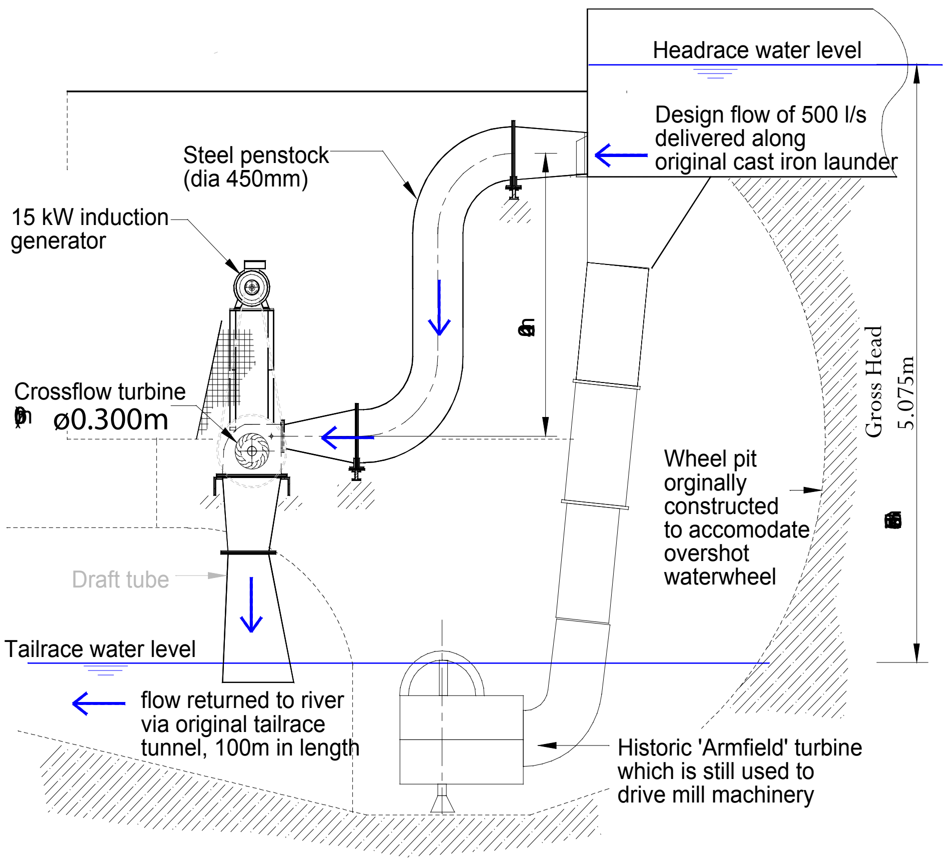
A steel penstock pipe diverts water from the old cast iron launder at the end of the leat into the crossflow turbine. The installation is supported by a series of steel beams which are secured in pockets in the walls of the old wheel pit. A draft tube underneath the turbine enables the full head of water to be utilised whilst keeping the turbine sufficiently high above normal water level to avoid submersion in all but the most extreme flood events. The electrical components of the system must be kept out of the water at all times. Since water level in the Mill can sometimes rise by as much as 2 meters, submerging the turbine, the generator and guide vane control motors are positioned on an extended framework which supports them safely above this level.

The turbine flow requirements are automatically adjusted to suit the flow available in the river by means of guide vanes at the inlet to the turbine. The position of these can be altered via linkages and a screw thread driven by small DC motors. The motors are similar in size and type to those used to power the windscreen wipers in commercial vehicles. A controls system receives a signal from a water level sensor at the end of the leat and opens and closes the guide vanes as required to maintain a constant head level.

A new grid connection point was established to the nearby three-phase pole mounted transformer. This enables all of the electricity generated to be exported. A power purchase agreement was set up with Scottish and Southern Energy who pay 6.5 pence per kWh for the electricity.

Scheme illustrations

Figure 6-2 Photographs and elevation of turbine installation at Gants Mill



Case study 2	Lemsford Mill
Site Location	Lemsford, near Welwyn Garden City, Bedfordshire OS Grid Ref. TL 220 124
System Manufacturer	HydroWatt GmbH, Karlsruhe, Germany
Installer	HydroWatt GmbH, Karlsruhe, Germany / Hydro Generation Ltd, Devon
Design conditions	Gross Head = 2.0 m Design flow rate = 1.35 m³/s
Hydropower system	A 'Zuppinger' breastshot waterwheel (dia. 4.2 m x width 2.0 m). Drive system: belt drive and gearbox transmission. (Speed ratio 1:100)
Generator	15 kW asynchronous, 3-phase, 1000rpm
Control system	Supplied by HydroWatt GmbH Water level sensor to geared DC actuator driven sluice gates and G59/1 grid connection unit with power factor correction, voltage and frequency trips
Energy Capture	Approx. 70,000 kWh per year
Project background and description	 *Figure 6-3 Lemsford Mill and tailrace* The listed former textile mill situated on the River Lea in the village of Lemsford was purchased by Ramblers Holidays Ltd who undertook a significant program of refurbishment in order to provide modern business premises for their 45 full-time staff. The new owners were keen to demonstrate their ethos of environmental sustainability and as part of the refurbishment, the feasibility of electricity generation was investigated by Hydro Generation Ltd. The study showed that a significant proportion the building electricity requirements could be met by hydropower and options using conventional turbines and modern waterwheel were compared.
System design and operation	It was decided that a modern version of a traditional breast-shot waterwheel, was the most appropriate solutions due to the considerable aesthetic benefit which the installation would also bring to the building. The new wheel has dimensions are very similar to those of the original which had disappeared. This enabled a close fit into the existing wheel chamber. The wheel operation is regulated by a control system which monitors upstream water level and adjusts the position of an overshot sluice gate and a second relief channel sluice gate. Battery back-up is provided to close the inlet sluice and open the relief sluice in the event of a problem. The system is simple to operate at the turn of a key and requires very limited maintenance. The power produced is exported to the grid on a net metering basis. This means that the power is consumed in the building if sufficient demand exists and otherwise exported. A separate meter is installed to measure generator output for collection of Renewable Obligation Certificates as these can be claimed for all electricity generated and not just the proportion which is sold to the grid.

Scheme illustrations

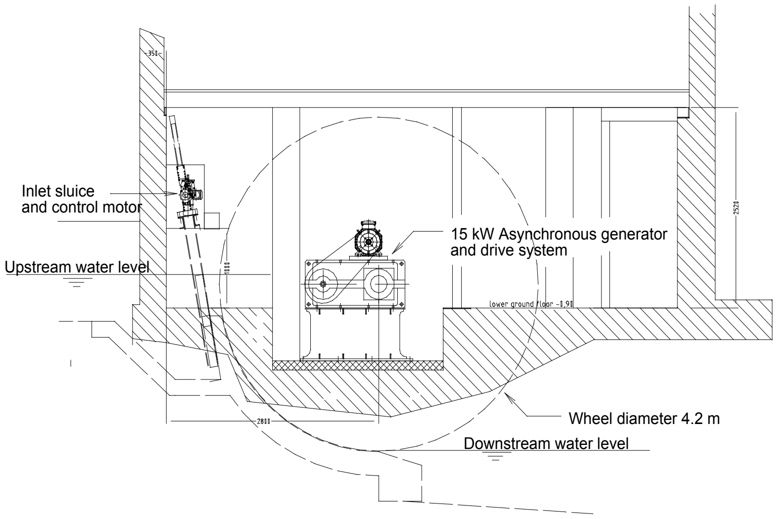


Figure 6-4 Elevation of new wheel installation

Figure 6-5 Waterwheel (bottom) and 15 kW Generator with drive system (top)

Case study 3	Shawford Mill
Site Location	Beckington, near Frome, Somerset OS Grid Ref. ST 792 533
Turbine manufacturer	Unknown
Developers	Clive Winterbourne / Malcolm Cooper / Hydro Generation Ltd
Design conditions	Gross Head = 1.3 m Design flow rate approx 0.600 m³/s
Hydropower system	Open flume turbine mounted in the base of a concrete tank. Flow regulation by means of adjustable guide vanes. V-belt pulley drive transmission. (Speed ratio 1:10)
Generator	5 kW asynchronous, 1-phase, 1000rpm
Control system	Supplied by GP Electronics Ltd, Devon. Water level sensor to DC linear actuator controlling and G83 grid connection unit with power factor correction, voltage and frequency trips
Energy Capture	Approx. 15,000 kWh per year
Project background and description	*Figure 6-6 Shawford Mill and mill pond*  This listed Somerset mill is located on the River Frome. The site was initially redeveloped for electricity generation using a DC generator in the 1940's supplying the neighbouring house and farm. The mill building has been leased by Clive Winterbourne who runs Altek Computers Ltd located a short distance away. Clive recognised that the site provided an excellent opportunity for refurbishment and updating. Although the head at the site is low (approximately 1.5 metres), the River Frome has a mean flow of around 3.6 m³/s at this point. The most costly part of low head micro hydropower schemes is often the civil building work. Since this was already in place, a decision was reached to refurbish the existing turbine, leat and tailrace rather than to completely redevelop the site at much greater cost. The help of millwright, Malcolm Cooper from Carom Water Crafts was enlisted to help refurbish the old turbine and drive system. Clive Winterbourne undertook the work to clear the leat and tail race of silt deposits and install the generator and electrical system. A new single-phase grid connection to the nearby transformer and export meter was installed by Distribution Network Operator, Scottish and Southern Energy plc. The system was commissioned by Hydro Generation Ltd. in November 2005.

System design and operation	This open flume design of turbine was favoured at a number of former mill sites where the head was low. A control rod enables operation of a linkage which moves guide vanes to direct the flow over the turbine. The position of this can be modified to maximise the turbine output under varying river conditions. The control rod has been linked to the grid connection unit via a linear actuator which is driven by a DC motor. This enables automatic start up and grid connection of the generator and automatic flow adjustment under varying river conditions.

Scheme illustrations

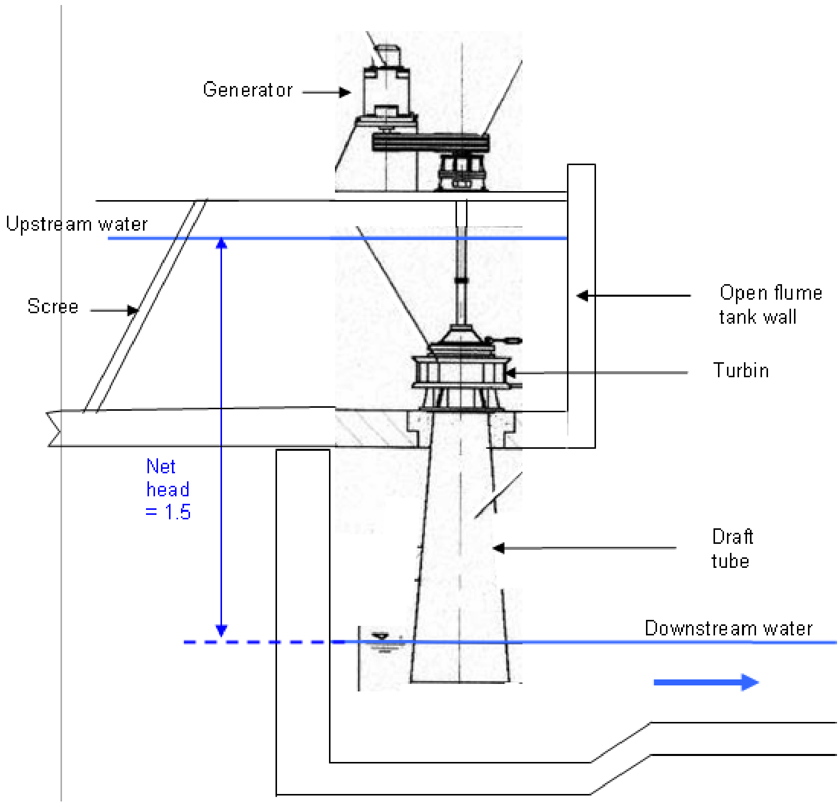


Figure 6-7 Elevation of open-flume turbine installation

Figure 6-8 Clive Winterbourne with new 11 kW generator (left) and Linear actuator which is used to operate the turbine guide vanes (right)

Further Information

The British Hydropower Association (www.british-hydro.org)

The British Hydropower Association is the trade association for the UK hydropower industry. It represents a wide range of interests including those of consulting engineers, manufacturing, design, investment and operation of UK hydro power systems.

UK Government Grants: Low carbon building programme (www.lowcarbonbuilding.org.uk)
The Low Carbon Building Programme will support renewable energy projects including small-scale hydro power. The scheme covers domestic, commercial and public sector applications at various grant levels. See www.lowcarbonbuilding.org.uk for details.

Manufacturers and developers referenced	Email / Website
Derwent Hydroelectric Power Ltd Derbyshire, UK	Email: jon.needle@derwent-hydro.co.uk
Dulas Ltd Machynlleth,Wales, UK	Email: webenquiry@dulas.org.uk www.renewable-resources.com
Carom Water Crafts (Malcolm Cooper)	Email: carolac71@msn.com
Gilbert, Gilkes and Gordon Ltd Cumbria, UK	Email: enquires@gilkes.com www.gilkes.com
GP Electronics Devon, UK	Email: gpelectronics@onetel.net.uk
Hydro Generation Ltd Devon, UK	Email: info@hydrogeneration.co.uk www.hydrogeneration.co.uk
Hydrohrom, Czech Republic	Email: info@hydrolink.cz www.hydrohrom.cz
Hydro Watt GmbH Karlsruhe, Germany	Email: HydroWatt@t-online.de www.hydrowatt.de
Ossberger GmbH	Email: ossberger@ossberger.de www.ossberger.de
Pico Energy Ltd	Email:info@picoenergy.co.uk www.picoenergy.co.uk
Powerpal UK Ltd	Email: websales@powerpal.co.uk www.powerpal.co.uk
Sustainable Control Systems Ltd Nottingham, UK	Email: info@scs-www.com www.scs-www.com
Valley Hydro Ltd Cornwall, UK	Email: valleyhydro@lineone.net www.valleyhydro.co.uk

Other organisations referenced	Contact
The Environment Agency	Tel 08708 506 506 www.environment-agency.gov.uk
Low Flows 2000 Institute of Hydrology Oxfordshire UK	Email: lf2000@ceh.ac.uk www.nerc-wallingford.ac.uk

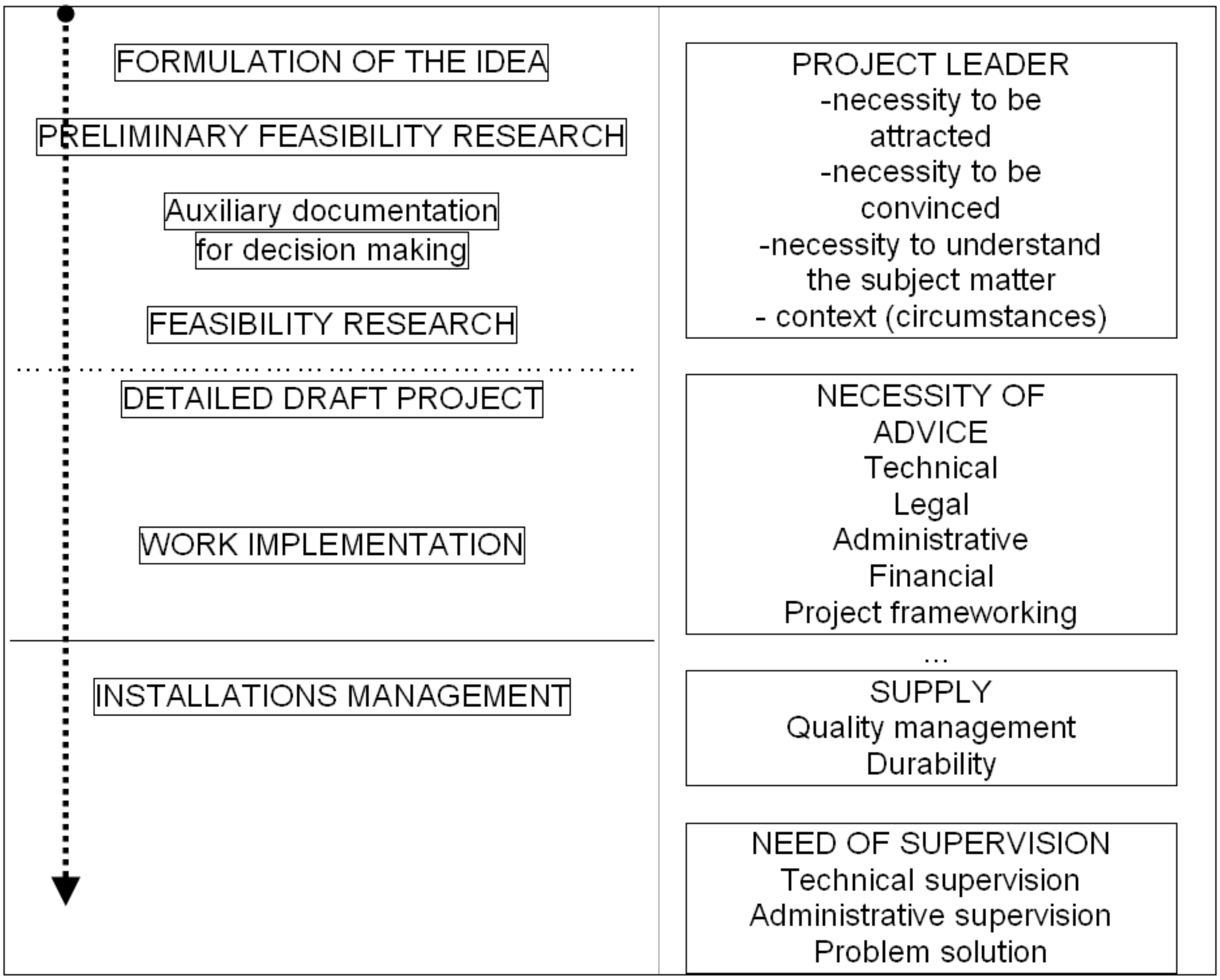
Electricity companies purchasing exported power from small generators	Contact
EDF Energy plc (London Electric, South West Electricity,	Email: Mark.Thompson@edfenergy.com
Scottish and Southern Energy plc	Email: James.O'Meara@scottish-southern.co.uk
Good Energy Ltd	Email: Nick.Haines@good-energy.co.uk
Green Energy UK Ltd	Email: ramsay@greenenergy.uk.com
Tradelink Solutions Ltd	Email: www.tradelinksolutions.com

ORGANISATION OF ENERGY PRODUCTION FROM RENEWABLE SOURCES - PART 1

Corporate plan

In order to implement a project for utilization of renewable energy sources (production of electricity or heat), it is necessary to pass through the following stages of project designing and formulation (see the diagram below)

Reference: «Manual for applying the Energy from Waste Wood Project ,



ADEME –Rhônalpénergie Environnement, July 2001

Project formulation: preliminary feasibility research

Before launching a project, it is important to revise the general project. For this purpose a qualitative estimate and a project description should be prepared. Therefore, the preliminary feasibility research has the purpose to inform, to convince and explain to all project participants the data, connected with the technical and financial ensurance as well as to give an initial notion for the economic profitability and the actual project implementation. This research is also the basis to support the project implementator in the finalization of its structure.

In case of thermal energy production facility, the following factors should be considered:

- determination of the envisaged heating network and the connected premises;
- evaluation of the envisaged equipment capacity;
- estimation of the envisaged replacement of energy from traditional sources with energy from renewable sources and the need of renewable fuels
- approximate estimate of the investments and the production costs

In case of electric energy production project, the preliminary feasibility research should include:

- availability of renewable energy sources in the region of project implementation (examination of the production spot, supply materials, etc.);
- market research: potential clients and what quantities?
- examination of the probable sale sectors;
- calculation of the installation cost and the operation cost. Determination of the initial profitability criteria;
- initial research on the possibilities for subsidies.

The preliminary feasibility research will allow the separate project participants to form a notion about its feasibility and relevance both from technical and economic point of view. The research will be performed by the project leader who would undertake afterwards the project implementation.

In case of heat production project, the opportunity to replace the traditional energy sources with renewables should be estimated and the project legal status should be checked. The replacement of fossil fuels with fuels from renewable sources should not be at any cost and under any conditions, taking the chance to demotivate the project participants. A detailed analysis should be made of the fuel types and prices as well as of the heat loss in the network. The choice of fuel can be motivated by the price, yet it can be the result of its social impact or, of the general notion, shared by the residents of a given area. Depending on the origin or the social impact, different types of fuel can be selected. For example, for a municipal wood-fired heating installation, the waste wood of agricultural origin may be preferable since, according to some local governors, in this way they will achieve "utilization of the agricultural areas", therefore, it is more socially significant than the waste wood of forest origin. Besides, it is recommended to draw up a prognostic operational account, containing preliminary evaluation of the main incomes and expenditures for the project construction.

It is at that stage that the negotiations for the sources and the fuel prices should be carried out.

Upon completion of the preliminary research, if the partners are willing to examine the project in detail, a more elaborate feasibility research should be made.

Feasibility research: Examination of the needs

Initially, it is important to specify the project type: heat production or electricity production for sale. Depending on the choice, the overall concept of the project would differ.

Thermal energy production

If it is a question of installation, designed to produce and distribute thermal energy, it is important to specify the needs and select the means for the successful project implementation.

Basically, the thermal installations produce energy, necessary for heating, but they can also be used for hot water supply for everyday needs.

In the design stage, the installation capacity required for hot water production for everyday needs can be supplemented to the capacity, necessary for heating.

Calculation of the overall capacity of the heating installation (ITEBE, 2004)

The overall **capacity** is determined according to the needs in very cold weather, for maximum conditional internal temperature of the premises. The conditional internal temperatures of the premises (Tint) are different, depending on the type of premises: from 14 to 15 °C for work rooms, 19°C for residences, from 21 to 24°C for retirement homes and hospitals. The notion "very cold" is determined on the basis of the basic ambient temperature towards the climatic conditions in the area of the premises. These data are available at the meteorological stations.

Here are several examples of basic temperatures:

Geographic zone	Basic ambient temperature (Text)
The Alps	- 10°C
The Ardenes	- 12°C
Paris basin	From – 5 to –10 °C
Flandria	- 9°C
Jura	–12°C
Vosges	–15°C
Seaside zones	–4°C

The basic temperatures vary, depending on the above-sea level of the locality. For a specific building, the heating capacity is calculated in kW by the formula:

$$Pchauff = \frac{G \times V \times (T\text{int} - Text)}{1000},$$

where: (P chauff) = P heat = heating capacity

- **G** is the specific heat loss coefficient in the building in W/°C.m3, and it is calculated on the basis of the building characteristics and the materials, used for its construction. Compliance with the RT 2000 Heating Regulations is mandatory.
- **V** is the heated area of the building in m3,
- **Tint** is the conditional internal temperature in the premises in °C,
- **Text** is the basic ambient temperature in °C.

The variation range of **G** is the following:

- About 0.5 W/°C.m3 for contemporary buildings with very good insulation,
- About 1 W/°C.m3 for buildings, meeting the operative regulations from 1984 on.
- About 2 – 2,5 W/°C.m3 for old buildings without insulation (built before more than twenty years).

The **capacity**, necessary for **hot water production** for **everyday needs** is determined on the basis of the following two parameters:

- everyday needs, depending on the type and number of consumers,
- installation type: accumulating or direct

The everyday needs of hot water are calculated in kW/hour per year by the following formula:

Q (energy to be supplied, in kW/h) = the hot water consumption for everyday needs (HWEN)

In liters per day x (THWEN – TCWEN) x 1,16 (TCWEN - cold water for everyday needs)

The production of hot water for everyday needs (HWEN) can be neglected in general, when calculating the capacity of a small community, an average individual home or institutions with low hot-water consumption (for example, schools and offices), since it is negligible.

It cannot, however, be neglected for buildings where the hot water consumption for everyday needs is high (HWEN > 10% of the overall energy needs), such as tourist buildings and hospitals, retirement homes and swimming pools. In these cases it will be necessary to make calculations in order to determine the capacity, required to meet these needs.

If the individual home is very well insulated (small heating capacity), a slightly higher capacity should be eventually envisaged in order to satisfy the needs of hot water, although the capacity of the smallest heating installations is often higher than really necessary.

Nevertheless, we have to mention the following:

- the accumulating systems for hot water production for everyday needs allow to decrease the necessary capacity (by restricting the power output), in addition to the fact that the storage capacities are considerable.
- In order to update existing installations, the necessary capacity can be estimated if previously there was a generator, designed for hot water production for everyday needs.

The **overall capacity** of the **heating installation** represents the sum of the previous two capacities:

Ptotale = Pecs + (Pchauff x Ppertes)

Ptotale (Pgeneral): the necessary capacity

Pchauff (P heat.): heating capacity

Pecs (PHWEN) : hot water capacity for everyday needs (if required)

Ppertes (Poss): For heating installations, supplying a remote heating network, the network losses should also be taken into account; usually, the loss percentage is very low. We have to comply with the instructions of the pipe manufacturer, with the network length, the desired temperature and the transfer velocity.

Calculation of the energy needs

The energy needs (corresponding to the useful energy - BesoinChauff) are calculated in kWh per year by the formula:

$$BesoinChauf = \frac{B \times V \times DJU \times 24}{1000}$$

where: BesoinChauff = heating needs

- **B** is the specific loss coefficient of the building in W/°C.m3, reduced with the available free sources (solar or internal). Usually, it represents 70 to 90 % of the G coefficient.
- **V** is the heated volume of the building in m3

- **DJU** is the number of Degrees Total Days, determined by the climatic conditions in the spot of the premises, in °C per day. DJU represents the annual sum of the differences from the ambient temperatures (by data of the meteorological statistics) and the desired internal temperature, for example, 18 °C.

Monthly DJU values, based on 18°C for some French towns

Town	January	Febr.	March	April	May	June	Sept.	Oct.	Nov.	Dec.
Agen	400	317	279	212	51	34	44	146	296	377
Ajaccio	299	249	242	182	80	11	5	63	168	260
Ambérieu	499	390	348	258	142	53	84	213	366	484
Angers	405	351	307	241	156	61	65	169	320	399
Angoulème	392	317	287	215	135	48	46	148	300	371
Annecy	569	448	404	297	184	92	111	252	409	543
Bastia	281	241	233	161	62	5	2	59	156	248
Besançon	500	405	358	259	113	66	84	220	374	490
Biarritz	315	254	246	204	11	41	26	100	224	302
Bordeaux	380	303	276	207	123	41	45	139	284	356
Bourges	452	366	330	242	153	57	73	190	343	434
Brest	363	332	326	276	202	117	102	183	278	336
Caen	419	372	350	273	194	103	93	194	314	387
Carcassonne	380	302	263	195	91	25	22	119	258	330
Cazaux	358	298	272	212	116	40	38	129	276	339
Chartres	458	401	349	267	105	80	90	211	355	440
Clermont-Fd	457	370	329	259	152	61	76	204	338	434
Cognac	390	314	284	213	123	40	44	146	294	365
Colmar	525	429	376	265	150	55	85	239	389	508
Dijon	498	400	348	238	144	51	68	214	375	491
Embrun	539	425	391	279	164	79	76	222	375	494
Gourdon	426	337	309	229	142	60	56	152	312	395
Grenoble	490	395	368	288	171	73	99	231	371	497
La Rochelle	371	314	282	215	98	42	36	127	263	355
Langres	540	458	411	299	199	98	115	250	417	516
Le Mans	430	374	321	248	156	64	79	189	334	409
Le Puy-en-Velay	523	421	399	316	206	100	112	250	390	482
Lille	467	409	372	290	184	96	105	218	352	445
Limoges	442	372	333	257	161	77	91	206	336	417
Lyon	471	369	327	234	124	39	62	192	347	460
Marseille	360	276	240	158	49	4	7	97	221	323
Metz	510	436	376	275	159	66	102	236	388	494
Millau	450	372	316	241	125	49	56	173	324	391
Montpellier	364	285	256	166	82	8	12	107	241	320
Mont de Marsan	384	310	273	205	101	35	43	149	288	364
Montélimar	425	332	290	192	87	19	30	141	297	398
Mulhouse	533	430	376	270	152	56	82	237	388	507
Nancy	518	436	384	284	100	72	106	246	393	493

Nantes	381	336	302	233	144	55	58	160	296	377
Nice	291	244	223	149	56	5	1	56	175	262
Nîmes	365	382	247	157	57	6	9	92	245	327
Orléans	457	390	340	266	167	73	82	206	349	436
Paris	450	388	338	244	125	61	76	198	345	432
Perpignan	316	253	218	144	48	4	6	70	198	279
Reims	478	414	361	278	90	72	93	225	366	453
Rennes	389	348	316	248	131	71	75	176	304	380
Rouen	457	399	386	297	196	110	111	217	354	434
Saint-Auban	375	281	245	160	52	6	9	101	230	345
Saint Quen-tin	478	413	369	283	178	89	101	221	371	462
Sarreguem-ines	501	430	371	270	152	56	100	231	378	490
Strasbourg	524	428	375	256	149	54	87	240	390	509
Toulon	275	222	215	135	43	3	2	48	157	238
Toulouse	400	318	277	211	102	35	37	139	293	364
Tours	431	359	323	244	151	61	68	183	336	418
Valenci-ennes	468	405	371	290	182	92	106	219	355	444
Vichy	466	372	348	274	170	63	83	210	345	450

DJU (degrees total days) are available at COSTIC for France, at the Standardization Agency for Switzerland and the Royal Meteorological Institute for Belgium.

The above formula allows to calculate the heating needs for the entire year at equal conditional internal temperature throughout the whole year. Since the buildings are not heated during the entire season and all day long at one and the same temperature, in order to calculate more precisely the needs, we'll have to include an additional factor – the periodicity:

Periodicity

The periodicity represents the time distribution of the heating needs. In the formula for calculation of the needs, the periodicity will equalize DJU. In order to explain better the periodicity factor, we'll give three examples:

main residence

- heating season : from the middle of October until the middle of May
- conditional internal temperature: 19°C in the day, 17°C at night

school building

- heating season : from the middle of October until the middle of May
- conditional internal temperature:
- in the period with classes: 5 days/ from 7 to 19°C in the day, 15°C at night and 2 days/ from 7 to 15°C day-and-night
- during the vacations and on holiday days: against freezing (8°C) day-and-night

retirement home

- heating season: from September until June
- conditional internal temperature: from 19°C to 21°C day-and-night

In order to calculate more precisely the heating needs, it is necessary to determine the DJU factor (degrees total days) in a more complex manner. For example, for a basic residence we have to take into consideration the sum of the DJU daily values (2/3 of which with Tint 19°C and 1/3 - with Tint 17°C) from the middle of October until the middle of March. Tint = the internal temperature.

Since this calculation is complex for quick estimation of the needs, we can usually be satisfied with an approximate calculation of the periodicity; for precise estimation it is recommended to resort to the services of a specialized designer's company.

DJU = DJU x coeff I

The periodicity depends also on the type of the building: the closer to value 1 (small periodicity), the more consistent its thermal needs (per day, week, or heating season). The periodicity is raised from 0.4 to first power, according to the density of residents in the building.

Examples of periodicity according to the type of building:

Periodicity coefficient		
High (coeff. I > 0,9)	Average (0,6 < coeff. I < 0,9)	Low (coeff. I < 0,6)
Hospitals	Common residences	Educational buildings
Retirement homes	Educational institutions with a boarding-house	Colleges, secondary schools
Swimming pools	Communal buildings	Festival halls, gymnasiums
Common residences	Premises with industrial process	Industrial buildings

Calculation of the energy needs for ECS
(HWEN hot water for everyday needs) are calculated in kWh per year by the following formula:

$$BesoinEcs = V \times 1.16 \times (Tecs - Tefs)$$

where:
Besoin Ecs = Necessity of hot water for everyday needs

- **V** is the annual quantity of spent hot water, in m3.
- **Tecs – Tefs**, is the difference between the conditional temperature of the cold water and the hot water in the mains (5 - 15°C).

The Hot water production for everyday needs in the summer, if the consumers' needs are not significant, the hot water production for everyday needs can be ensured by another generator (gas, electric, solar, additional heating facility), which allows stopping of the main heating system.

Calculation of the biofuel consumption expressed in kWh/ per year, is deducted from the above-mentioned heating needs by the formula:

$$ConsommationBois = \frac{BesoinChauf + BesoinEcs}{\eta \times PCI},$$

where: ConsommationBois = waste wood consumption
BesoinChauff = heating needs
BesoinEcs = necessity of hot water for everyday needs
η is the overall efficiency of the heating installation: the annual efficiency of the boiler, of the thermal transfer (heating network), of the distribution and the heat exchange. It can be approximately calculated between 60 to 85%.
PCI = the lowest fuel caloricity, expressed in kWh per ton or in kWh per cubic meter.
Therefore, the fuel consumption is expressed in tons or cubic meters towards the PCI value.

Electric energy production

When the issue is electric energy production, the starting point will be the market capacity to acquire the produced electric energy and not the need of electric energy. Actually, many European countries have undertaken the commitment to buy the entire electric energy from renewable sources and in long-term aspect the purchase contracts would appear more or less attractive, depending on the foreseen investment payback.

In order to produce electric energy, it is important to take into account several factors. First comes the possibility to sell the produced electric energy – whether a national policy for purchase of electric energy from renewable sources has been adopted or not. For example, in France it is purchased by EDF (Electricité de France – the National Electric Company) at fixed price (about 0,0787 Eurocents per kWh produced electric energy by the methanization process) for a period of time, which may vary from 10 to 15 years. The second factor to take into consideration is the availability of resources: wind, a high-flow river, solar climate, manure in sufficient quantities to be used on permanent basis, etc. The last factor is the financial status of the project participants.
On the basis of these factors, a feasibility evaluation can be assigned to a consultant's company.

Resources availability research
Depending on the type of utilized energy source, it will be necessary to estimate its availability (quantity, periods of availability). Besides, the factors, having impact on the availability should be examined and measures for its provision should be undertaken. It is necessary to prepare technical characteristic of the source, too. For example, a waste-wood technical characteristic would include granulometric composition, pellet sizes, etc. In addition, the probable deviations in the source quality should be estimated as well.

The evaluation of the various sources includes different parameters. For example, a wind –power installation may require preparation of a wind map.

Distribution markets research
The framework of electric or thermal energy production will require an evaluation of the possible markets for sale of this energy. The research and finding of such markets should be done long before launching the production.

When, however, it is a question of a small installation for the heating network, in most cases the project leader tries to find the energy source and not the market, and, what is more - in a small geographic region. For example, the farmers-members of the CUMA society can offer waste wood from the hedge trimming as a fuel for the heating network of the rural municipal building. In such cases, the project for the heating network construction should be discussed from the very beginning by all local participants. Here the fuel price is not a restricting factor, since the project promoters are ready to utilize the local sources of waste wood.

In the case of already built and well-structured production networks for deliveries (for example, the forest farms), the cooperatives and the associated forest owners can participate in biddings for supply with materials or, they can make direct offers to potential leaders of large projects.

If, however, we wish to produce electric energy, it is important to ensure its purchase and the connection with the grid. In France EDF (The National Electric Company) has undertaken the obligation to buy the entire quantity of electric energy, produced from renewable sources (wind, sun, biogas, etc.). Before starting the construction of a new installation for electric energy production, the following steps should be made in order to obtain a permit for electric energy production:

- a declaration or an application should be filed for operation permit, pursuant to the requirements of Regulation of 7 September 2000 to the Ministry of Industry, Small and Medium Companies, Trade, Crafts and Consumption (DGEMP-DIDEME –Electric Systems Subdivision - Télédoc 122 - 61, Boulevard Vincent Auriol - 75703 Paris).
- an application should be filed to the manager of the grid, preferred by the producer for connection of his production facility (to the manager of the local electric distribution network or the manager of the electric power-line network).

If we wish the electric energy, produced by our installation to be purchased by EDF (the National Electric Company of France), we would have to undertake some additional steps:

- an application should be filed to the Regional Directorate of Industry, Research and Environment for issue of certificate, entitling the use of the purchase obligation in the manners, provided by the Decree of 10 May 2001;
- an application should be filed to EDF (or another distributor, not national, if the installation is on the territory of its authority) for purchase contract by the order, provided in the price tariff for the specific types of production (for example, Decision of 8 July 2001 for the wind power).

These procedures are independent and can be done both separately and parallel. It is possible other legislations to require other permits. If necessary, for example, to obtain a permit for construction of electric energy facility, it will be issued by the Municipality. In some cases, a report for the project environmental impact might be requested as well.

Marketing research: how to attract all – both producers and consumers of electric energy?

This is a significant stage if the question is about implementation of projects for collective small-capacity heating networks, for which the partnership is of key importance for the undertaking. In this case it is really very important that all participants are concerned, involved in the project and actively participate in its implementation.

Similar stage is not envisaged in the projects for electric energy production or for construction of large heating networks since the partnership relations among their participants are not so close (the relations client-supplier prevail)

Operative legislation research

The research on the operative legislation is aimed at two objectives:

- acquaintance with the legal restrictions, related with the installation; for example, in a project for electric energy production from wind power, the legally established minimum distance between the wind park and the residential buildings should be observed.
- providing for the eventual risks of project rejection by the administrative authorities (denial of construction permit, etc. …)

The project should be well sustained both in regards to the national legislation and to the district and municipal regulations.

Legal and financial project organization

In order the project to be as profitable and as close to the initiators' expectations as possible, it will be necessary to select the most appropriate legal form for commercialization (transformation into a commercial product) of the materials, on the one side and, on the other – for the sale of the produced energy (thermal or electric).

The financial project organization includes three elements, which will be performed parallel with the legal one:

- analysis of the initial capital investments
- eventual search of investors
- eventual search of subsidies or investment funds

Different legal forms exist for commercialization and material use. The choice depends on the project's "ideal purpose". If it is a question of a multi-partner project, it is recommended to examine the cooperative organizational forms. They will be discussed in the second part of this Module. If it is a question of production or sale of new services only, on the contrary - one single classical legal form of companies can be selected (limited liability partnership or company, joint-stock company, sole proprietorship, public company, etc.).

A perfect type of company for all types of activity practically doesn't exist. Every incorporation of individuals selects the type of company that will meet their needs best. In order to make the most successful choice, it is advisory to get acquainted with the advantages and disadvantages of the most common types of companies.

The description of the separate types of structures, given below, is presented for the sake of information only. We have to comply mandatory with the operative legislation in the country of project implementation.

For each type of legal form we'll examine the handicaps, accompanying the establishment, the method for liability allocation as well as their advantages and disadvantages.

Type	Description	Establish-ment	Responsibil-ity	Advantages	Disadvan-tages
A not-for-profit company (com-mon partnership)	The not-for-profit company is the type, most widely used. If, for example, a fam-ily couple possesses a common agricul-tural business, from legal point of view this is a not-for-profit company. This example shows that the establishment of a similar company doesn't require any administrative proceedings. It doesn't mean that a written agreement is not required – it might help for the easier settlement of probable conflicts. The appearance of contradictions is one of the major problems for the not-for-profit companies. The character of the entre-preneur's relations can be the reason for insoluble arguments and this might result in company termination. If an op-posing article doesn't exist, each of the members can demand property alloca-tion and company dissolution. Legal entity: the not-for-profit company is not a legal entity; the entrepreneurs themselves bear the responsibility; they may elect one of them to represent the company.	Establish-ment: No ad-ministrative procedures, (oral or tacit agreement) but a writ-ten contract is recom-mended	Each of the entrepre-neurs bears responsibil-ity	Immediate establish-ment of the company	Personal relations and responsibil-ity, no legal entity estab-lished
Association	The associations are voluntary incorpora-tions of people, created for a definite period of time for achievement of one common objective. There are for-profit and not-for-profit associations. The for-profit associations are required to posses a permit to perform a spe-cific activity, issued by the competent authorities. Practically, very few such associations exist. The associations of legal type 1901 (France) are not eligible to receive profit. Their purpose is to foster ideas. For this reason they usually represent counseling bodies, engaged with assignments and advice in behalf of their members. Ac-cording to the Austrian legislation for professions in the field of industry and commerce, an association can also be engaged with for-profit business (for example, purchase-sale of agricultural product) if its chairman possesses a per-mit for business activity. Yet, pursuant to the law, a similar activity is an exception for an association whose main purpose is promotion of ideas. This activity is admitted only if undertaken as a means to achieve the objectives of the associa-tion, which are within the public best interests. Legal entity: the association is a legal entity, which exists and operates under a definite name.	The mem-bers should prepare a company memoran-dum	The respon-sibility and financial provision are undertaken by the com-pany	Low estab-lishment expenses, flexibility in member replacement	This type of company is appropriate for promo-tion of ideas, yet not al-ways eligible to receive profit

Type	Description	Establishment	Responsibility	Advantages	Disadvantages
Cooperative society (Cooperation)	The cooperative societies are organizations, formed to make purchase or submit favourable conditions to their members. They are especially suitable for incorporation of a large number of people. They are legal entities.	Memorandum of association of the cooperative society, subscribing to a control authority and a mandatory filing in the Trade Register	The responsibility depends on the type of cooperative society	Flexibility in member replacement	Expenses for audits; the members of the cooper. society, resigning it, do not receive any share of the capital increase of the company
Trade companies	There are for-profit limited joint-stock companies and for-profit common partnerships. Basically, they are subject to the same legal regulations as the limited joint-stock companies and the common partnerships, although this application is restricted mainly to the agricultural sector. The partnerships and the common limited joint-stock companies are eligible to run only commercial business in contrast to the commercial companies, which are also engaged with production. Legal entity: it is not a legal entity but it is possible to acquire rights in behalf of the company (for example, purchase of terrains, undertaking obligations or appearing in the court as a party).	No formalities but a written contract is recommended	Each member bears responsibility, Exception: the manager of the trade company or of the common for-profit limited joint-stock company is liable with his entire property while the liability of the limited joint-stock company's members is restricted	Easily established; the company may acquire rights in its behalf	Unequal status of the members of the common for-profit limited joint-stock company since they don't have equal liabilities
Limited liability company (Ltd)	This is the most frequent company in France (S.A.R.L.). Social conditions: • Majority manager (above 50% of the company shares); statute of non-receiving payment (similar to the sole proprietor) • Minority manager or manager with equal participation (= no less than 50% of the shares); statute of employee, pursuant to the general conditions of the social contribution system • Taxes: the company is subject to company tax (profit tax) without exceptions and the remuneration of the manager(s) is deducted from the profit	This is a company limited by shares	Requirement for at least two subscribers; the nominal capital amount is 7622 € (in France). Larger establishment expenses than for the sole proprietorship. The basic characteristic of Ltd. is the restricted liability of the partners up to their share participation. One or more managers run the company.	*Restricted liability within the limits of the share participation. *Easily changeable structure *Opportunity under certain circumstances the manager to have social insurance benefits in the capacity of receiving a salary *"Commercial" aspect	*Establishment expenses and the need of professional assistance: lawyer, expert-accountant *Formalities in the operation of the Ltd. *The manager is responsible for his errors and can be legally prosecuted

Type	Description	Establishment	Responsibility	Advantage	Disadvantages
Joint-stock company	S.A. in France Legal entity: this is the typical share capital company. It is engaged with considerable projects. There are two categories of joint-stock companies, as the second one is not frequently applied:the "Classical" Joint-stock company, run by the Board of Directors (with no less than three managers), nominating Chairman of the Board of Directors and General manager (optional)Limited Joint-stock company, run by the Board of Directors, which nominates Chairman of the Board of Directors under the surveillance of the Supervisory Council, which nominates Chairman of the Supervisory Council. General managers can be appointed as well. Taxes: The company is levied with a company tax and the executives' remuneration is deducted from the profit. Social conditions: The executives of the company: The Chairman of the Supervisory Council, The General Manager, the managers, the members of the Board of Directors and of the Supervisory Council receive remuneration under specific conditions	A minimum of 7 members required and a nominal capital amount of 38 112 € (in France). Half of the amount should be free during company formation. Larger establishment expenses and the need of professional assistance: lawyer, expert-accountant	The shareholders' liability is restricted to their share participation. The executives are responsible for their management errors and for violation of the company rights and may be legally prosecuted.	*The shareholders' liability is restricted to their share participation; *Flexible structure, facilitating the partnership; *The executives are eligible to receive remuneration *Social security benefits on the remuneration only *Activities, easy to be assigned; *Solvency of the partners	*Establishment expenses and formalities ; *Slow operation; *Obligation to appoint auditor; *The executives also bear legal responsibility
Sole proprietorship	Currently this is the most frequently applied legal form of small company. It is recommended due to the low risks and investments. Physical person: When one person – the entrepreneur, uses part of his property and time to practice independent professional activity, we speak about own business. The company proprietor acts as a physical person. Taxes: Total income tax is levied on the company proprietor pursuant to the tax category of Industrial and commercial profit. Social conditions: not receiving remuneration	Easy establishment. The company proprietor can handle alone the establishment formalities directly at the company registration center. The price is not high. Capital deposit is not mandatory.	The company proprietor is unlimitedly liable for his debts with his professional and personal property. The company property coincides with his property.	*Mandatory nominal capital is not required. *The establishment and operation are simplified. *The company proprietor has freedom for his decisions and is not obliged to report to any partners.	*Unlimited liability. *Limited social protection of those, not receiving remuneration.

Type	Description	Establishment	Responsibility	Advantage	Disadvantages
Private limited liability company	(EURL in France) Legal entity: this is not a new type of company. This is a Limited liability company, consisting of one subscriber. Taxes: Category of Industrial and commercial profit, paying mainly Income tax, similarly as the sole trader The single member may choose to pay company tax (profit tax). Social conditions: the Manager-member does not receive remuneration. Exception: if the manager is a third person, he will have the statute of employee and will receive a salary.	Only one subscriber is necessary and a nominal capital amount of 7622 € (for France). The establishment expenses are higher than for the sole proprietorship.	The liability of the single member is restricted to the deposited share, yet it can be extended on his personal property in case of management errors. A manager runs the company.	*The liability is restricted to the share participation (except for the bank guarantees) *Opportunity to choose payment of company tax, thus reducing the social security installments. *Property transfer is facilitated. *The transformation of the company into Limited liability company is facilitated. *"Commercial" aspect	*Establishment expenses and the need of professional assistance: lawyer, expert-accountant. *Operational formalities. *The manager is responsible for his errors and may be legally prosecuted (guarantees). *He has the statute of not receiving remuneration

Source: ITEBE, 2006

Technical Organisation

The technical organization of the project is performed in accordance with its objective (production of thermal energy or electric energy) and the selected legal form. The following should be defined for each participant:

- the level of his technical participation;
- his possible financial participation
- the level of his responsibility during project implementation.

Parallel with this and during the feasibility research, the following stages should be completed:

- **Phase 1:** profound technical project consideration: plans, discrimination of the design stages, depending on the competent authorities to be involved and precise formulation of the technical assignment. This stage will include the initial proceedings before the competent authorities (especially in case of electric energy production) for grid connection and electric energy purchase. As a result, the technical part of the bidding documents will be elucidated, on the basis of which offer announcements will be made when project implementators will be sought. The first indices for the project profitability will be calculated.

- **Phase 2:** formal project presentation before the competent authorities in order to obtain operational permits.

- **Phase 3:** preparation for completion of the practical work. This phase is a continuation of the previous two; the purpose is to achieve the best possible preparation for the forthcoming works, especially the construction work, which will be assigned to specialized companies.

- **Phase 4:** preparation and publication of offer announcements. During this stage all participants shall gather in order to consider and finalize the technical conditions contained in the bidding documents as well as the assignments of each of them during the separate stages of project implementation.

- **Phase 5:** selection of project implementators through examination of different offers, prepared for every stage of the technical project implementation.

- **Phase 6:** construction start-up, control and supervision. Permanent control of the construction expenses and their compliance with the profitability threshold, specified in the very beginning.

- **Phase 7:** acceptance of performed works and determination of warranty terms for them.

- **Phase 8:** check of the compliance between the invoices and the actually completed works (accounting audit of the compliance between the budget, provided in the technical terms and conditions, and the invoices).

- **Phase 9:** follow-up of works and documentation. This stage allows finding out operational faults that might appear before the expiry of the warranty term and be acknowledged by the companies-manufacturers. Permanent control is required for the energy consumption as well.

If necessary, the financial project profitability will be calculated and corrected for each work stage.

Determination of the installation management method – conclusion of supply and delivery contracts

Determination of the installation management method

In case of installation, common for a given group (municipality, private persons' association, etc.), especially if it is a thermal energy installation, one of the following management methods can be selected:

- Direct community management
- Vicarious management contracts
  - Concession
  - Lease
  - Through a manager
- Public -municipal management

Direct community management

In case of direct community management, the community undertakes the overall management and provision with own human and material resources. According to the general rules of the territorial communities, three possibilities can be envisaged:

direct management : municipal service, included in the municipal budget,

financially autonomous management: the budget, allocated for this activity is set aside from the municipal budget, yet it is approved by the municipal council. The city council is in charge of the service.

financially autonomous management by legal entity: the budget is independent and is managed by a managing board, appointed by the city council. The community performs periodic monitoring. In this case the community is the person in charge, therefore, it is responsible for the financing, for the construction work management and for the installations commissioning.

Vicarious management contracts

In relation to the vicarious management contracts, in the first place it is necessary to specify three conditions: allocation of responsibilities, method for contract conclusion, and method for tariff determination.

Since the allocation of responsibilities will be between a public party under the contract (the community) and one or more private persons (managers), it must be most explicit, especially as concerns the allocation of risks, connected with the construction of the installations, with their funding and operation. The participation of private persons can be in various forms, the most popular among which are: the lease and the concession.

First, the tariff should be determined on a public discussion, regardless of the selected management form. It should be determined on the basis of an initial prognostic calculation of the operational costs and on the basis of a price-updating formula, which reflects the changes in the economic environment. In case of major changes in the conditions for lease (change of the fuel prices, of taxes and fees, etc.), the initial contract should allow price updating – periodical or, each five years. The leaseholder may be a local mixed economic company, a private or a public person.

Note: The local mixed economic company (SEML – in France) is a private joint-stock company, the majority share of which (50% to 80%) is possessed by the community and, the remainder – by private persons. Its public objective is contained within the framework of the authorities, entitled to the local community. Source: "Subsidiary Manual for the Energy from Wood Project", ADEME –Rhônalpénergie Environnement, July 2001).

- **The concession:** the first form of vicarious management represents "re-authorization to perform a definite public service at own risk". It might be given to a private person or a private company. The overall and complete responsibility for the service provision is borne by the concessionary who finances at his own risk the creation of the distribution network, the maintenance and operation. His remuneration comes directly from the consumers. For compensation of his initial investment as well as during operation, the concessionaire receives remuneration or income from the price, paid by the consumers of the service and usually possesses the monopoly. The duration of the contract should allow the concessionaire to regain his investments. That is why the concession contracts are usually long-term (from 12 to 24 years).
- **The lease:** the management of an already existing network is conceded to the leaseholder who hasn't contributed to its creation financially. His activity involves thermal energy supply for the consumers, maintenance of the network and implementation of certain activities. He receives his remuneration mainly from the consumers. The lease contract should be for a definite period of time. More specifically, the concessionaire invoices the cost of a public service, used by the consumers and pays a tax to the public person.
- **Management by a manager:** it refers only to the operation of the service from installations, already built by the community. In this case the invoicing of the service and the tax collection are done by the community which, afterwards, pays remuneration to the manager in compliance with a preliminary agreement.

Public – Municipal management

This type of management is a mixture between lease and management by a manager. The community preserves the ownership, undertakes the operation risks and receives all amounts, paid by the clients, eventually through a manager. He takes care for the execution of the company's technical assignments and is directly subordinate to the community.

Advantages and disadvantages of the separate management forms

	Direct management	Mixed management	Vicarious management		
	Public corporate management	Public-municipal management	Lease	Concession	Management by a manager
Advantages	Control of the objectives and management policy. Implementation of public services	Operation control Interest in the profit	Income for the community on a regular basis Shorter term	Construction funding is not necessary. Usually quality service Devolution of responsibilities	Risk sharing Previously agreed remuneration
Disadvantages	Very strict rules for public accounting. Necessity of qualified personnel. Financial risk for the community	Operation risk for the community	Network funding The leaseholder works at his own risk	Long-term contracts Necessity of strict control (price audit, maintenance ...)	The manager is only service implementator

Definition of the material supply contracts

If it is a question of fuel purchase, it is highly recommended to conclude a contract with the seller in order to guarantee the quality and quantity of the fuel deliveries in future. Usually, the seller is the one to offer a contract; yet, this can be arranged by mutual agreement between the parties. The contract shall mandatory include:

- description of the fuel, delivered for the installation
- terms of delivery (transportation, frequency, annual distribution)
- terms of payment for the fuel and terms of price changes (indexation formula) as well as the terms of contract cancellation.

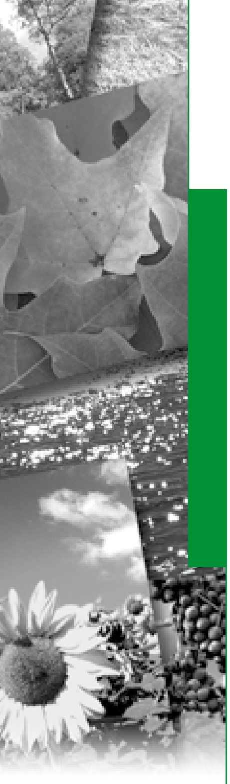
The contract shall include different terms and conditions, depending on the purchased fuel. For example, for the waste wood the purchase should be defined either in tons, or in cubic meters, or in KWh.

Definition of the contracts for thermal energy supply

If the issue is thermal energy production for sale, contracts shall be concluded with the buyers. The contract should be prepared so as its term to coincide with the term of the contract for thermal energy sale, in this case no less than 10 years and, preferably – with the term of equipment depreciation (from 15 to 18 years for the networks for thermal energy production, fired by waste wood). The contract shall contain explicit definitions of the responsibilities, the services limits and the terms for thermal energy supply.

Definition of the contract for electricity supply

If it is a question of electric energy production facility in France, EDF (The National Electric Company) is obliged to purchase the entire electric energy, produced from renewable energy sources. For this purpose EDF and the producer conclude a model contract; it is confidential and shall mandatory include the purchase price per kilowatt and the duration of the purchase obligation.



ORGANISATION OF ENERGY PRODUCTION FROM RENEWABLE SOURCES - PART 2

Preparation of territorial multi-partner projects for energy production from renewable energy sources

Important note: This module is based on

- The methodological work, implemented within the frames of the SOQLE Project (Local Organisational Employment System), funded by the European Social Fund within the frames of the EC Equal Program.
- The experience of the network of Societies for Agricultural Materials Utilization "CUMA"in France

Introduction

This module is focused on projects for promotion of energy production from renewable energy sources, characterized by utmost complexity as concerns the partnership establishment.

The content is based mainly on the experience of the network of Societies for Agricultural Materials Utilization CUMA in the field of adding energy value to the waste wood of agricultural origin. Actually, the wood – energy source (obtained from waste products after hedge trimming or pruning of cultivated forests, such as quickly growing willow clearings) is an opportunity to diversify the agricultural range and a potential source to promote activities on the agricultural territories under development. The implementation of these projects involves activation of a collective platform for management of the production of wood as an energy source. This platform unites different partners from one territory1, agricultural or not, local institutions….. which, usually, do not work together and which shall have to "invent" a way to function in order to achieve one common objective.

This module proposes a tool to structure the partnership, based on legal approach. This approach allows bringing out in a strict and specific manner the issues, connected with distribution of the partners' roles.

This tool is examined briefly in the more general aspect of the separate stages of a project development.

Determination of the project framework

The first stage of a project management requires an overall concept for the separate project elements (what it is about)

Project identity map

- ***Title of the project***

- ***Territory / number of residents***

Specifying what territory will be suitable for the project. If this territory does not coincide with the administrative or territorial division, what would be the consequences?

- ***Political and technical team to maintain and manage the project***

Who has ordered, invented and set up the program of the present project?

- ***Origin and context of project promotion***

Determination of major facts (local issues / political will, etc.…), which justify the project development.

Outlining of the local factors (previous common experiences/ conjuncture events / public activities, etc. …) which precede the project launch.

- ***Objectives and tasks or strategic framework of the project***

Determination of the project objectives, which outline the framework of its intervention on the specific territory.

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1. Territory: this notion is used here in the sense of natural (space, landscape, environment, ….) and human wealth (crafts, skills, organizations, ….). The territory is a space for project preparation in proximity.

Specifying the project objectives and the common goal, specifying the operative objectives, expressed by the most precise quantitative and qualitative indicators.

What results do we want to achieve?

- ***Clients***

Determination and characterization of the separate types of clients (profile, solvency, expressed needs)

- ***Competition in the geographic area of project activities intervention***

How is it expressed?

To what extent the project might contradict, i.e. impede other local initiatives – private, organizational or non-governmental?

- ***The established partnerships and their specific contribution to the project***

Making a list of public organizations, associations or private persons who have formal contribution (joint funding, submission of means, partnership agreement) in one or another moment of the project development.

Besides, pronouncement of those to be involved in some activity who cannot be considered partners and, of the participants in the meetings.

Reconsideration of the project logics

In a project for energy production from renewable energy sources, the partnership is expressed in joint activities with exactly determined objective, which are performed by different actors (participants) on one and the same territory and, in the specific cases we are examining – the partnership is between persons occupied with agricultural activities (farmers) and persons, not occupied with agricultural activities. The partnership formation corresponds to the stage, consisting of organization of multiple relations among the necessary actors so that the project can be started. Therefore, here comes the issue for the legal form of the project.

Very often this issue is formulated simply: do we have to establish a trade company, shall we found an association, etc. The initial asking of questions passes through the legal forms. Actually, in order to find out the precise legal formula, one should take into account the project objectives so as to define what the lawyers call l' affectio societatis.

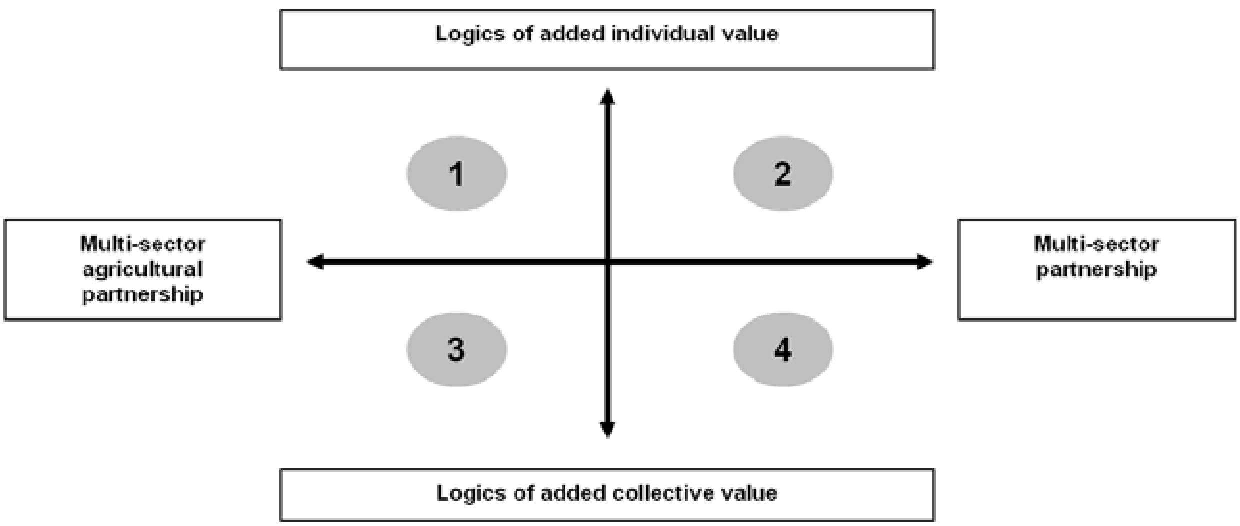
L' affectio societatis is a Latin expression, meaning the intended element, necessary to establish a relation between the persons, who have decided to subscribe to the capital of a given company. The existence of l' affectio societatis allows the company to be distinguished from the Trade unions of the co-owners, from some incorporations, from the associations….

That is why it is appropriate, before everything else, to outline the intentions, implied by the partners in the project; the legal structure will be shaped out by these intentions.

The projects for energy production from waste wood, so far known to us, can be schematically divided into two trends:

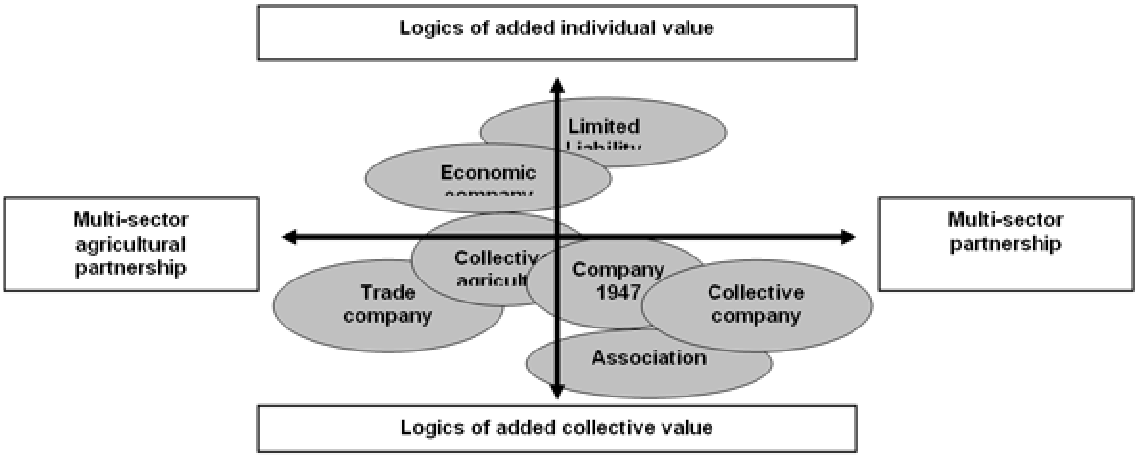
1. The first trend characterizes the partnership overtness of the project. It is not a question of understanding the diversity of clients for the service; it is rather determining who shall have the authority to take decisions for the project: is it exclusively agricultural or, it is shared with the local administrative units, with the craftsmen, the associations; is it proportional to the possessed capital or, it is democratic, etc. The more overt the activities to the partners, the more restricted will be the involvement of the "classical" agricultural legal structures.

2. The second trend provides information whether the project objective is collective or individual. Here it is a question of specifying the logics, which will predetermine the use of the economic result: either the result will be targeted for allocation among those who invested in the structure (logics of returning the investments and an added individual value) or, the result will be re-invested in the collective economic project in order to add value and promote the activity of the business (logics of added collective value).



In this way we can divide the projects according to four major trends:

This allows defining four dominant, non- exclusive logics, which combine:
1. Energy production from waste wood as diversification of the agricultural range
2. Energy production from waste wood as a new commercial activity
3. Energy production from waste wood as a new collective and cooperative agricultural project
4. Energy production from waste wood as a project for territory development.



In compliance with these dominant logics, which steer the project, different legal forms can be suggested. Each legal structure possesses its own rules, which will correspond in one or another extent to the project aspect. Therefore, the choice of legal form shall be made according to the following key issues:

- who takes the decisions (people, occupied with agriculture or, people not occupied with agriculture)?
- in compliance with what qualities (allocation of the right to vote according to the invested capital or, one person = one vote)?
- what would the results be used for?
- what would be the object of the legal structure (who does what)?

If we apply the French Legal Code to the above diagram, we'll obtain the following diagram:

REMEMBER: The objectives – not the activities of a project determine the legal entity.

Company:
An entrepreneur organisation that submits products and services by focusing the progress of men and women on the core of its strategy. This form of organization is based on one and the same values:

Individual and collective success: the company fosters the progress of the individual through the common success.
The progress of democracy and autonomy of the actors: namely, every member of the company has the right of one vote during ballot, regardless of the invested capital.

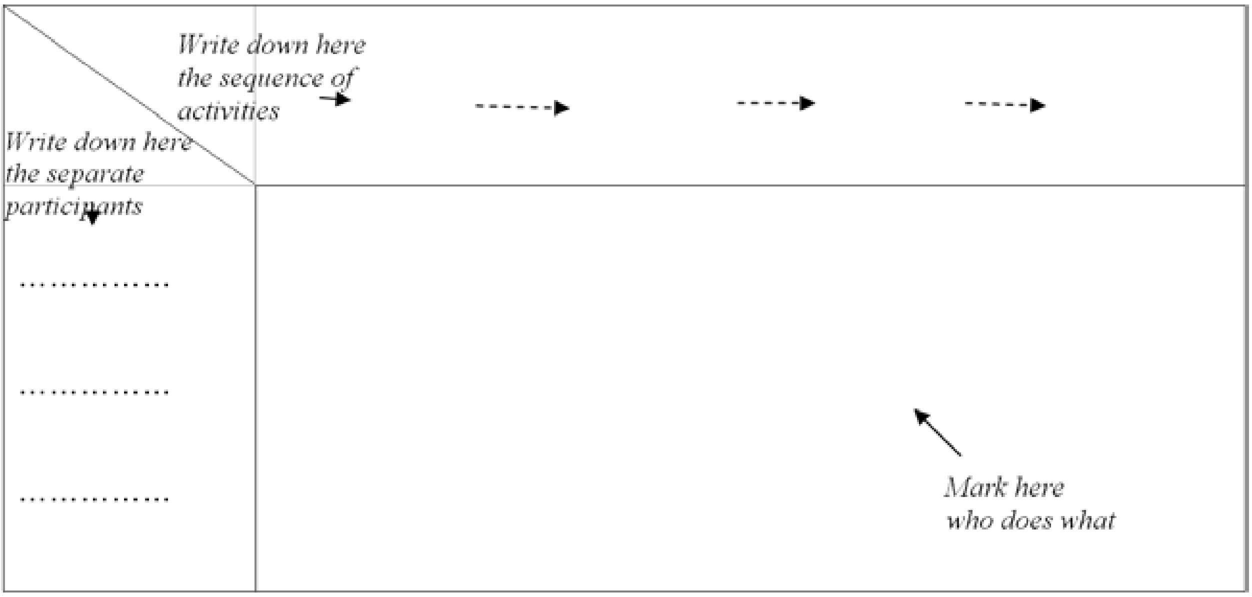
The demand for impartiality and solidarity, allowing organization of production in behalf of all partners without any discrimination or individual acquisition of profits. The produced surplusses will be directed mainly for enforcement of the economics and for the partners, depending on their activity. Requirement for proximity.

Partnership structuring

Presentation of the partnership organisation
In order to analyse and correctly manage the activities, involving many partners, we suggest a graphic method for presentation of the partnership organization.
This graphic presentation allows focusing the attention of the project leaders on one major issue: a **multi-partner project doesn't have a "magic" legal organization**, capable of solving all problems. Primarily, it should be well considered who would intervene in the project, at what moment, why, in order to propose afterwards types of legal organization, corresponding to the desires of the project participants. **There isn't "a magic box" to put in the legal issues and to take out key solutions.**

Therefore, before pondering on the legal organization, it is better to consider the following issues: Who does what? Who decides what? Who participates? Who doesn't participate? Who will offer services and/or will be partner? Who funds what? From this point of view it is already time that some projects specify their answers: this is the objective, pursued by this management method.

This approach is restricted: it refers to projects, built around an evidently distributed production, such as the projects of the Societies for Agricultural Materials Utilization CUMA for energy production from renewable energy sources.



Graphic presentation of the sequence of activities

Introductory definitions:

- Partnership chain: the partnership chain is a sequence of elementary legal relations between the partners (units), forming one harmonic entity.
- Unit (in a partnership chain): unit here is defined as an elementary legal relation, connecting two partners.

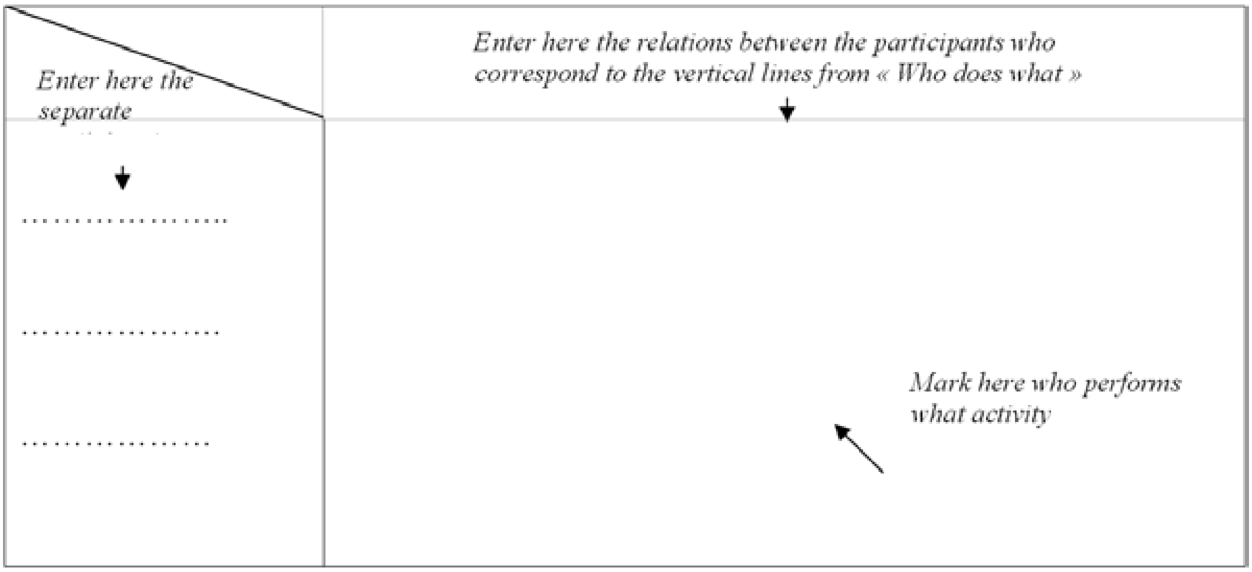
Drawing up a graphic presentation of the partnership organisation

Stage 1 – making a list with the sequence of envisaged activities

Stage 2 – making a list with actors (participants) and involved persons

Stage 3 – presentation of the sequence of activities (Who does what?)

It is recommended to define clearly who and where intervenes in the project. That is why we draw up a table in two directions:



Graphic presentation of the partnership organization

- In a line - distribution of the series of activities
- In a column - distribution of the list with participants
- Finally, it should be mentioned who intervenes for each activity; the points in the table should be connected and the table should be made easy for understanding. That is how the organization of the production process appears.

Stage 4 – drawing up the table of the partnership organization

Include the list with the participants in a new table. In the table for the sequence of activities (Stage 3), all vertical lines should be marked, which, actually correspond to a legal relation between two participants. All these lines should be transferred in the form of units in the new table. That is how the new organization of the production process will appear.

Each unit corresponds to an exactly specified legal framework, which is better to be explained and secured with a view to the project duration.

- Incorporation in the collective structure
- Submission of services through companies or associations
- Conclusion of public deal with the local company

In this way all legal issues in question will be analyzed.

These four levels divide into parts the legal structure of the partnership, specifying our situation and the specific questions, arising thereof.

In this way the partners are placed in a concrete situation in order to explain their respective roles and relations.

Project construction: analysis of the separate constituent elements

Research on the possibilities for technical-economic implementation

This stage is here in order to remind. After having an outlined initial diagram of the partners' organization, its economic application should be specified. Therefore, at this stage it is important to study again the technical-economic implementation.

The slips, referring to the separate types of energy, contain the specific elements, necessary to make a research on the technical-economic implementation.

Concomitant functions

It is a question of management, of leading, of external representation who runs the affairs? who communicates and explains to external people ? who coordinates? who is in charge? These functions are an indivisible part of the experience: who executes them? who funds them? The recording of these functions might reveal new actors and new legal units.

Synthesis: formulation of the project

This stage is important in order to enable the partners have a clear notion about what has been done so far and what is the stake of the project, outlined with work proceeding.

The idea of a multi-partner project of this type is not a linear process. The partners, their roles and objectives can develop, depending on factors, internal and external for the project. Therefore, it is of primary importance to approve every stage in order to comply with the pursued common objective, which will mature with the time.

For example, if we go back to item 2.1.2, logics of the partnership, which is orientated exceptionally towards individual added value and direct investments return, it might grow into a more collective approach when the partners get to know each other and begin to trust.

Therefore, the time necessary to establish a partnership, should not be neglected.

Actually, it is important to take into account this probability of change when the legal form is being selected. The issue is about taking into consideration the possibilities to transfer from one legal form to another and to be aware of the cases when a return would not be possible and which would do so as the selected organization will turn unsuitable and unfit for the project development.

What is a Society for Agricultural Materials Utilization « CUMA »?

CUMA is a Society for Agricultural Materials Utilization, which unites a minimum of four individuals, occupied with agricultural activities, who have decided to buy and use together agricultural products.

There isn't any restriction in regards to the maximum number of the people, occupied with agriculture. It is recommended the CUMA society to be within moderate human limits, i.e. a group of individuals who know each other well and who usually work together.

The CUMA society is often municipal or even includes several municipalities. Some CUMA societies are on a district-division basis, due to the specific character of their activity and the amount of their investments (drainage, compost fertilization, ….)

The CUMA society observes regulations and internal rules.

The Regulations specify the general rules to function, to bind, and determines the obligations in the CUMA society.

The partners are bound in the form of capital, allocated in shares.

The internal regulation, prepared by the CUMA society, is specific as concerns the material utilization (planning, maintenance, recovery, …), its unit price (this unit can be an hour, a hectare, an area, ….).

In order to ensure the function of the administration and the execution of the representative functions, the members of the CUMA society nominate the employees to execute the administrative functions, who – on their turn, elect a President at least, a cashier and a secretary. Every year they should conduct an annual meeting in order to submit the financial report and to discuss the investment projects.

The basic elements, connected with the activity of the

CUMA society are: materials, remaining after forage collection, from soil cultivation, from manure spreading, transportation, ….., storehouses for materials with repair shop and, sometimes workers.

The CUMA society may perform all agricultural activities. In addition to the economic interest, connected with the activity, the CUMA society is also a place for exchanging experience, along with firm solidarity among its members. On this basis the CUMA societies contribute to the development of their territory.

CASE STUDIES

1) Supply of municipalities with pellets from agricultural waste wood from one CUMA society and one Economic company

Partners
Structures / Activities / Contacts

- Municipality
- Specialist of steam heating assembly
- Farmers
- Local entities (district, region)
- ADEME (Environmental and Energy Management Agency): this public institution under the aegis the Ministry of Ecology and Sustainable Development and the Ministry of Industry and Research has the purpose to evoke, be in charge of, coordinate, facilitate and implement activities, whose objective is environmental preservation and energy management.

Developed activity
whose results have already been achieved

The small municipality in question, with 560 residents, has selected wood pellets as a heating source for the public buildings – a retirement home and five municipal buildings. The Mayor has decided for this type of heating in order to preserve the forests as well as to « return the money for heating back to the municipality ».

This type of activity is really profitable for the farmers in this area: it allows both to add value to a waste product (waste wood) and to add social value to the participants – the image of the pollutant is transformed into a person whose actions are positive and acknowledged in the life of the municipality.

The annual municipal consumption of wood pellets reaches 650 m3 and the private persons also use wood for heating.

One CUMA society was created by nine farmers (today they are 18, and the CUMA societies are 2) to share one crushing machine, one telescopic loader, one crane and one storehouse in order to provide the wood pellets, necessary for the municipality. Its commercial turnover in 2002 was a little above 7 000 €.

The Economic company, involving members of the CUMA society, was established in order to turn the wood pellets into a subject of trade in the municipality. About ten private individuals are also supplied by this company. Its commercial turnover in 2002 was 16 000 €.

Historical survey

47% of the territory is afforested. The forest consists of 60% deciduous trees (oak, beech, chestnut-trees) and 40 % coniferous trees (spruce, Douglas fir-tree). The production of wood for heating is traditional: the region has been supplying Paris since the beginning of the 20th century. In the 80-ies, the use of wood for energy production rapidly increased on the territory of the municipality as a result of which it became a Natural Regional Park.

Yet, a project for collective heating in a municipality from adjacent canton failed recently due to lack of coordination between producers, fitters and consumers. Downcast, the local people are restrained about the resumption of this type of experiment.

In 1987 three farmers, one specialist in steam heating assembly and one technician, interested in the process of wood production for heating, united their knowledge in order to create a common operating project. At that time the farmers disposed of a large quantity of waste wood from forest rarefaction whose market value was very low, even zero, but this had no meaning for the crushing machine.

After many visits to different places and biannual experiments, the group finally succeeded to produce pellets from wood, suitable for the normal operation of the heating installation.

In 1990 one CUMA society and one Economic company were established in order to supply the boiler rooms with wood pellets.

A dozen of private persons were equipped with semi-automatic and automatic heating installations, fired with wood: these installations allowed scattering the doubts in regards to reliability, efficiency and comfort, offered by the wood energy.

Actually, the project was substantiated in September 1993 through collective boiler room, servicing one retirement home and five municipal buildings.

Present organization

1. FRACTURING / The farmers produce wood pellets in their farms by means of the crushing machine of the CUMA society,

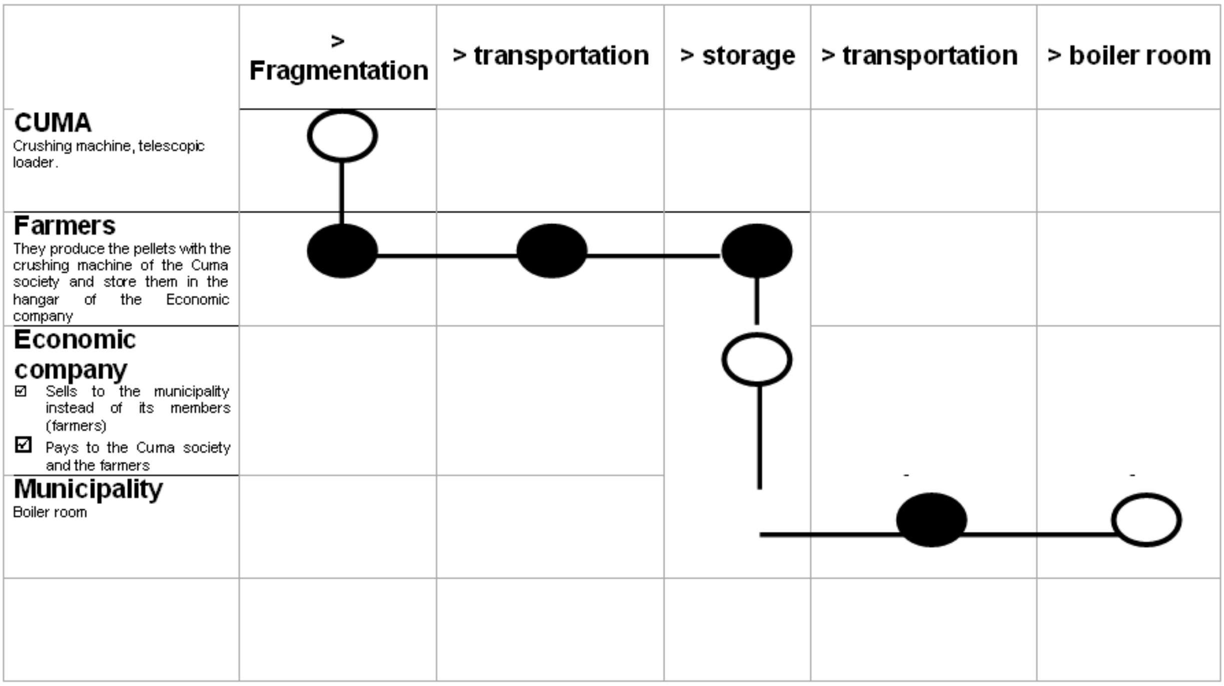
2. TRANSPORTATION > STORAGE / The farmers convey the pellets to the hangar of the CUMA society by own means (tractor, trailer); they use the telescopic loader of the CUMA society and declare the quantity of delivered pellets.

3. The SALE is ensured by the Economic company.

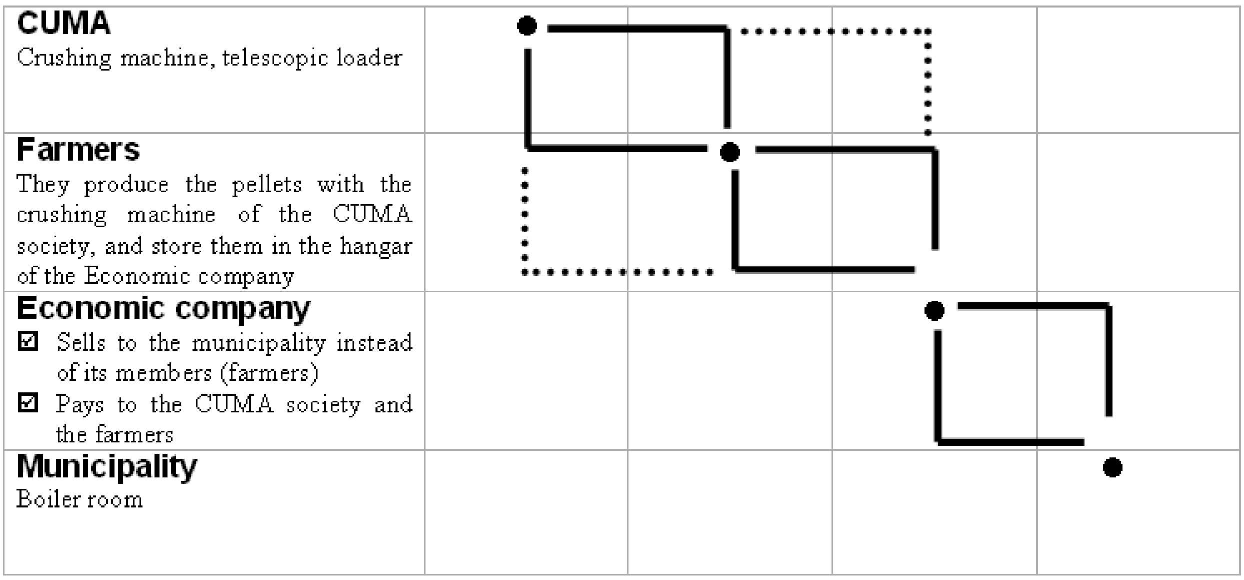
4. TRANSPORTATION > BOILER ROOM / The municipal workers convey the wood pellets to the municipal heating installation and replenish the expended quantities

- The municipality pays for the wood pellets to the Economic company,

Graphic presentation of the sequence of operations



Graphic presentation of the partnership network



- The Economic company pays to the CUMA society the expenses for the services of its members as well as the salaries of the farmers.

Funding
Assistance by ADEME in regards to investments.
The municipality finances the boiler room.

Innovations
(inclusive encountered difficulties)

The municipal boiler room, using waste wood energy, participates in the energy development by renewable energy sources, in maintaining the employment in the agricultural area through activity diversification and, in the management of the forest inheritance.

2) Production of pellets by agricultural wood and transforming them into a commercial product by one CUMA society and one Cooperative society with common interest

Partners
Structures / Activities / Contacts

Local participants
- The CUMA society possesses a crushing machine; it is used by the entire municipality
- The farmers, using wood pellets
- Several private persons, using wood pellets and currently being supplied by a society (anonymous society)
- The Association of municipalities (16 municipalities, 7300 residents)
- The Municipality (1200 residents)

The technical partners
- The Chamber of Agriculture (in charge of the « project » group)
- The FDCUMA society (in charge of the « project » group)
- The General Assembly

Historical survey

Local political will
Selected persons from some municipalities were willing to suggest alternative solutions for energy supply and proposed installations, fuelled with natural gas and fragmented wood. This is how the project for wood heating installation for the retirement home and the municipal buildings of the Association of municipalities was launched.

The first consumers of wood pellets
Private individuals among the local residents also installed heating installations, fired with wood pellets. They take care for the supplies themselves (if they are farmers) or, they buy pellets from a company. Actually, the farmers use the pellets as animal bedspread.

The farmers use the crushing machine of the CUMA society for production of the pellets. This crushing machine is going to exceed soon its capacity and should be replaced: the persons in charge of the CUMA society are willing to invest in a larger machine, equipped with a gripping device.

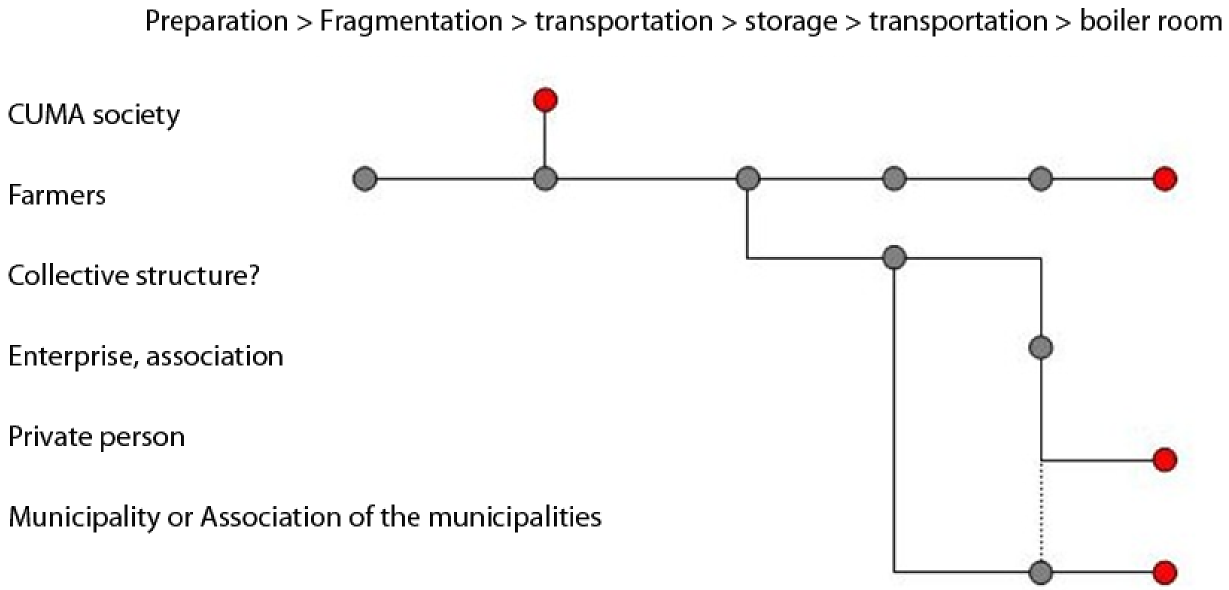
In this context a « project » group was created to investigate the development of a local agricultural cycle for wood pellets production.

Activity to be developed
The activity to be developed is the production of pellets from agricultural wood by the farmers in order to utilize them for own needs and sell them to private persons or local communities, having individual or collective heating installations.
A project exists for one Cooperative society with common interest to ensure the production and to turn into a commercial product and make promotion of the energy from renewable energy sources, originating from local natural resources, to which value is added and, specifically, from waste wood by the bushes.

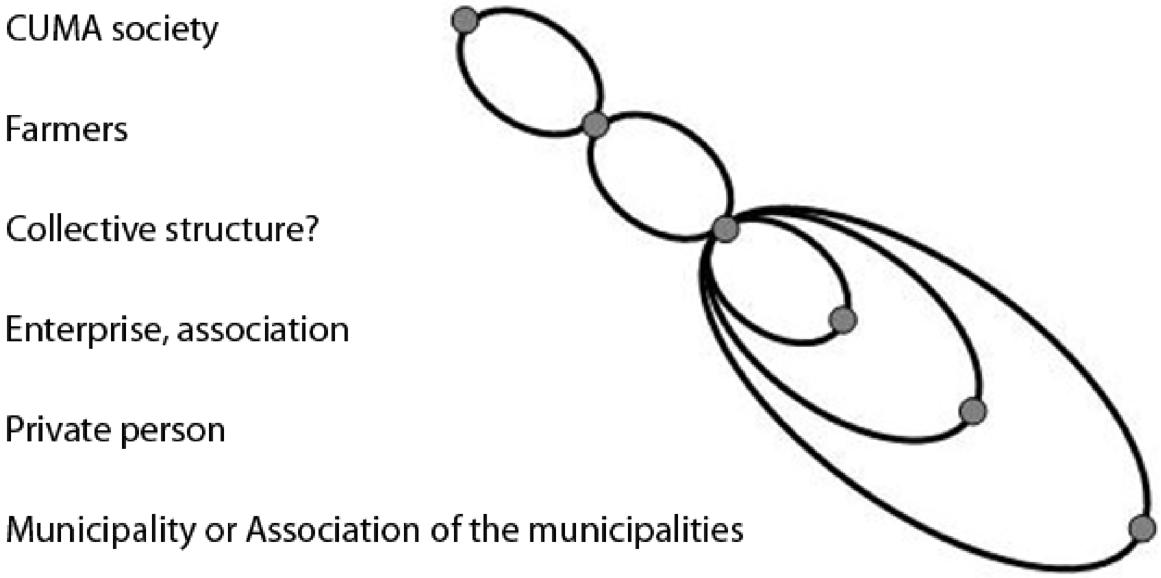
Composing the colleges of the Cooperative society with common interest /SCIC/:
Note: the college is not a legal organization with special rights or such as to entitle its members to any special rights. It is a question about a tool to organize the right to vote depending on the number of members or the obligations of the partners.

- Category Hired workers: the hired worker - partner in the Cooperative society with common interest;
- Category Clients: private persons or legal entities that supply themselves from the Cooperative with common interest with pellets by fragmented wood to feed individual or common heating installations.
- Category Producers: the farmers produce the pellets from fragmented wood according to the terms and conditions of the contract which they have concluded with the Cooperative society with common interest for purchase;
- Category Private persons or legal entities with interests, common or connected with the Cooperative society : 2 CUMA
- Category Local Associations: the Association of the municipalities, which is supplied by the Cooperative society with common interest with pellets by fragmented wood to feed the common heating installation.

Graphic presentation of the sequence of operations



Graphic presentation of the partnership network



Note: each vertical line from the previous diagram represents a particular legal relation between two participants in the project, a relation which is represented below by a circle. A definite legal framework corresponds to each circle that might be specified through analysis on a later stage.

Organization

5. PREPARATION / The farmers prepare the area of their cultivated land to perform the fragmentation

6. FRAGMENTATION / The farmers produce on their cultivated area wood pellets with the crushing machine of the CUMA society. The CUMA society can help by hired workers.

7. TRANSPORTATION > STORAGE / The farmers – with their own machines (tractor, trailer) – convey the pellets to their own platform for storage (own use) or, to a public platform for storage.

8. TRANSPORTATION > BOILER ROOM / Transport company and/or the municipal workers convey the pellets to the individual or common boiler rooms.

Funding

- Subsidies for equipment
- Sales of wood pellets

3) A project for promotion of local cycle of energy production from waste wood with agricultural and non-agricultural resources

Partners

Structures / Activities / Contacts

Local participants

- The CUMA society is a group of 50 farmers which possesses a certain infrastructure (hangars). The society is willing to make the investments, necessary for fuel production, which is provided by a local member-supplier or, by the farmers themselves, for their own heating installation.
- A lumberman from an adjacent municipality disposes of a large quantity of wastes, such as wood chips and scrap, which have no value. He is willing to supply the common heating installation.
- The municipality has launched a project for construction of a retirement home with 32 beds. The building will be equipped with a wood-fueled heating installation. The expected annual consumption is 500 m3. A heating network project, including the gendarmerie and the school is under research process.
- One farmer possesses a heating installation fuelled with wood pellets, and about ten others are interested in it. Each of them needs provisions from 50 to 100 m3.

The technical partners are united in a technical committee, presided by the Association of municipalities.

- The Chamber of Agriculture: with the mediation of its regional specialist, the Chamber of Agriculture is a key factor for the project launch.
- The Association for Energy Development by Renewable Energy Sources will both inform and educate, and will render technical assistance to the project creators.
- The FDCUMA society accompanies the incorporated CUMA society (preliminary technical-economic research on the CUMA investments, necessary for the society)
- Regional Centre for Forest Property: research on the wood resources, recommendations for the technical part.

Steering Committee of the project, which includes the Regional Council, Ademe and selected members of the Association of municipalities.

Developed activity

whose results have already been achieved

- ✓ Selling to the local community wood pellets for the heating installation in the retirement home
- ✓ Dividing the investments and the management of the necessary funds for development of the cycle for energy production from waste wood between the farmers and the foresters (crushing machine, gripping device, tractor, trailer, drying hangar).

Historic survey

In 1996, by initiative of the regional specialist of the Chamber of Agriculture, a visit of wood-fuelled heating installations was organized for several farmers. Actually, the Mayor of the municipality was impressed by the waste wood energy utilization in the public infrastructure and ordered a research on the possibilities for creating a heating installation (assigned to the society) for the future retirement home, the gendarmerie and the school.

One farmer was equipped with a wood-fuelled heating installation; others are pondering on the issue.

The CUMA society and a local lumberman are willing to develop a local network for pellets production in order to feed these heating installations. Besides, the lumberman envisages to conclude a contract with the municipality for pellets supply and to use the crushing machine of the CUMA society (2002) for this purpose.

It is in order to ensure the sustainable supply with provisions that the financial partners of the operation change this scheme and demand the establishment of a collective structure to procure the resources and to negotiate with the local community (in this way to avoid the relation with one supplier only). This structure can be in the form of a Collective society with common interest (SCIC) in order to be able in the future to develop other management activities in this area.

Organization

9. FRAGMENTATION / the lumberman produces pellets from waste wood with the crushing machine of the CUMA society

10. TRANSPORTATION – STORAGE and then TRANSPORTATION TO THE HEATING INSTALLATION / the lumberman conveys the pellets to the storage hangar by own transport means and after that delivers the pellets to the municipal boiler room.

- One (several) farmer(s) produces (produce) for himself (themselves) wood pellets with the crushing machine.

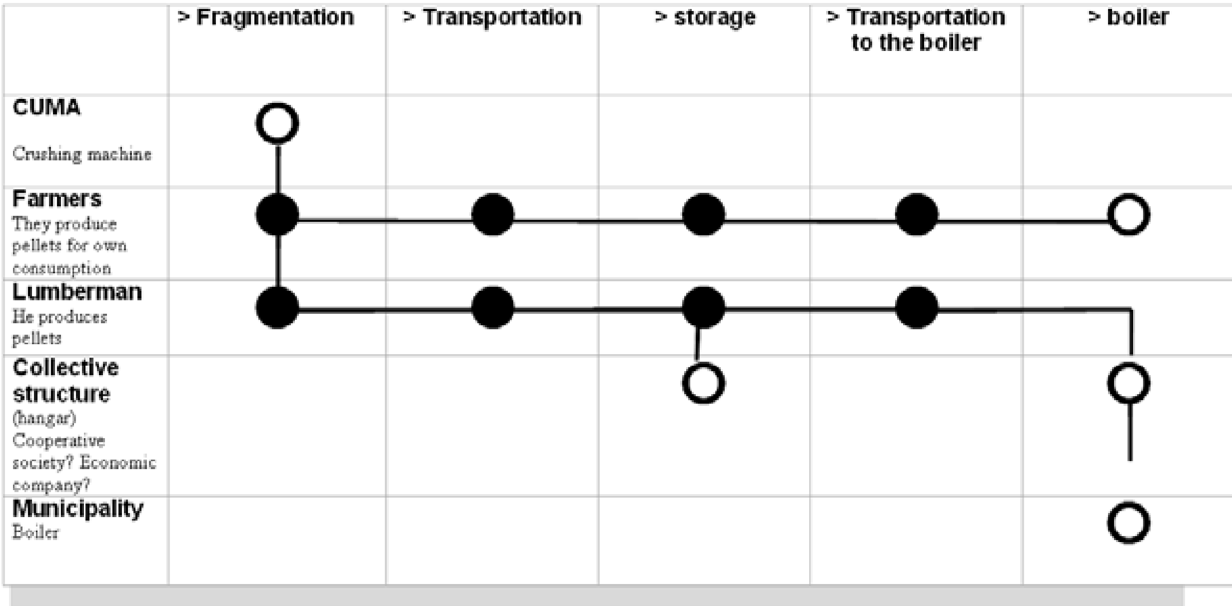
Funding

- The Ministry of Ecology
- Regional Council (Directorate Energy)
- General Assembly
- The Ministry of Agriculture (Loans)

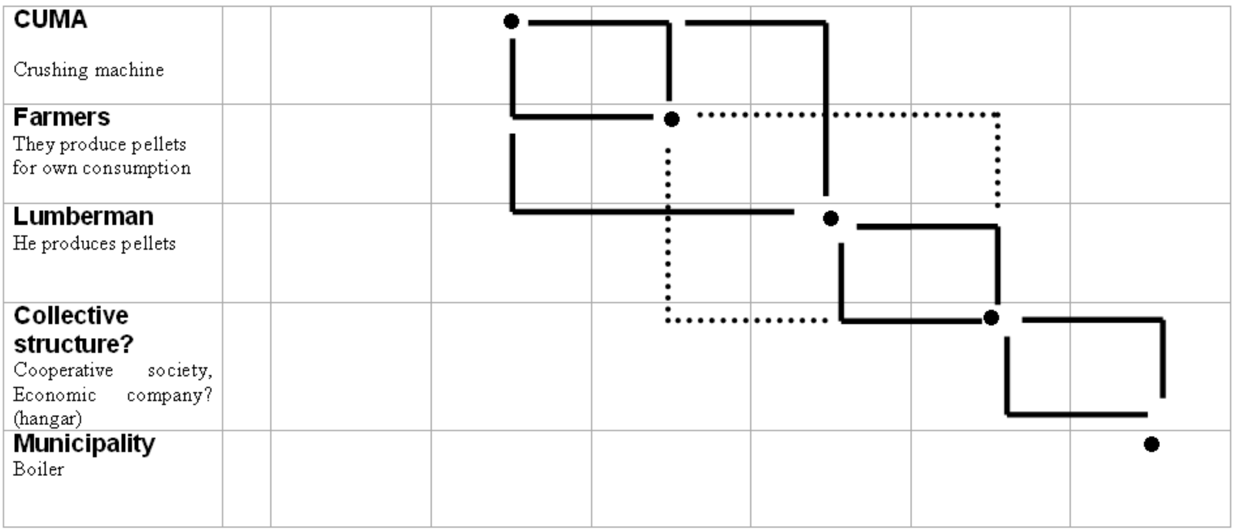
Innovations
(inclusive encountered difficulties)

The promotion of production cycle for wood pellets on this territory facilitates the demand for energy independence. In addition, it contributes to the prevention of clearings, occupying the limestone plateaus, although the trees that spoil the landscape are not suitable for fire wood production.

Graphic presentation of the sequence of operations



Graphic presentation of the partnership network



APPENDIX: INFORMATION FOR SOME FRENCH LEGAL ENTITIES

GIE – Economic company

The establishment of an Economic company is not precisely « establishment of a firm », it is rather a possibility for « development of already existing companies ».

Actually, it allows to many already existing companies to regroup in order to facilitate or develop their economic activity, along with preserving their independence.

Subject of activity

The subject of activity can be private, commercial or agricultural, depending on the activity of the Economic company.

The activity of the Economic company should be a continuation of the economic activity of its members, and not a substitution.

Members

The Economic company can be established by at least two members. There isn't any restriction for the maximum number of members.

It can be run by physical persons or legal entities.

Every member of the company shall practice such economic activity as to be continued by the activity of the Economic company.

Financial commitment

The Economic company can be constituted with or without capital

- **With capital** : there are no requirements for minimum capital.
  he ways to receive and release an apportionment are determined on a free basis by the Company statute.
  The natural apportionment should not be evaluated by an apportion commissioner.
  The pecuniary means, deposited in cash, should not be a subject of deposit.
  It is possible to make a production apportionment. The capital might be changed.

- **Without capital:** the company functions as an association: the members pay voluntary instalments if the company services are invoiced and the accumulated cash reserve turns out to be insufficient.

It will be possible to make an apportionment in cash, a production apportionment or, a natural apportionment.

Liability

Basically, all members are liable jointly and unrestrictedly for the debts of the company to third persons except when this liability is not determined, limited through a contract with a third person.

Functioning

- The Economic company is run by one or several managers:

The founders determine on a free basis in the constituent contract of the company the administrative details (one or several managers, nominated among the members or not, duration of the mandate, manner of election …) Basically, these issues shall be resolved by the Assembly of members. The authorities of the managers are also specified on a free basis. Yet, the restrictions of the authorities are valid only in connection with the company members. In regards to third persons, the managers engage the company with each action, involved in the subject of activity of the company.

- The General Assembly consists of members of the Economic company.

It has the right to take all decisions under conditions, specified in the constituent contract of the company. If there isn't an explicit order, the resolutions shall be passed unanimously.

- It is mandatory to designate one or several persons who will control the management :

These are always physical persons, whether members of the Economic company or not, who have been nominated by the Assembly of members. Their role is to ensure management control in compliance with the conditions, provided in the statute of the company.

Fiscal conditions

The Economic company is not subject to taxation in this capacity.

- Every member is subject to taxation for that part of realized profit of the Economic company, which represents Total income tax for him/her (category Industrial and Commercial Profit, Agricultural Profit, Non-commercial Profit according to the type of company activity) or, he/she is subject to company taxation according to the circumstances.

- The Managers – members of the company are subject to the same terms.

- The Managers – Non-members of the company are subject to the conditions for salaries and pecuniary remunerations.

Shares of the members (physical persons) of the Economic society

- Share of persons, not receiving salary

They receive their due part of the company profit.

- General share of persons, receiving salary

In order to benefit from it, the company members shall:

- receive remuneration in exchange of their activity,
- exercise efficient activity which should be paid for, and which should be different from the one, executed in the capacity of company member.

Transfer

The transfer of company shares requires unanimity except when provided otherwise in the contract.

Registration fee: (at the account of the person, acquiring it): fixed fee of 230 Euro.

Main advantages

Decreased expenses and less establishment formalities.

Considerable flexibility and freedom of operation.

Minimum capital is not required.

Opportunity to unite financial means.

Main disadvantages

Joint and unrestricted liability of the members of the Economic company.

Necessity of pool, therefore – of good understanding between and among the company members.

SCIC – Cooperative society with common interest

Form

The Cooperative society with common interest acquires obligatory the form of Anonymous company or Limited Liability company.

Subject of activity

The subject of activity of the Cooperative society with common interest is "production or supply of goods and services of common interest, which are socially useful". The great stake here is to find out a medium position between the human demands and the economic obstacles.

Third persons, not members of the company, may use the products and services of the Cooperative society with common interest.

Members

A minimum of three types of members is mandatory in order to establish a Cooperative society with common interest (SCIC):

- workers at the cooperative society,
- users, beneficiaries,
- every other person :
- volunteer
- public associations, within the limits of 20% from the company capital of the Cooperative society with common interest
- persons who contribute with all other means to the activity of the cooperative society.

Right to vote

According to the general principles of the society, every member is entitled to one vote in the General Assembly.

Colleges

The members may group in colleges (a minimum of three).

The notion « college » should not be obligatory identified with a given category. In this sense a college can unite many categories of members according to geographic areas or, field of activity, etc.

The incorporation into colleges is specified in the company memorandum, keeping in mind that one college may have a minimum of 10% and a maximum of 50% of the votes. Basically, all colleges have equal number of votes.

Control

The Cooperative society with common interest should be accredited by the Prefect for five years. Each five years the financial status of the society shall be checked up as well as its management manner (audit of the Cooperative society).

Financial regulations

Fiscal system: currently, the Cooperative societies with common interest are within the sphere of the fiscal system of the general law.

Reserve capital: it cannot be divided among the company members

- the reserve capital , legally established : one tenth of the company income is used to form the reserve capital;
- statutory reserve: the statute of the company specifies the annual dotation for the statutory reserve. It cannot be less than 50% of the available capital after making the legally established dotations for the reserve capital.

Subsidies: the public partnerships may subsidize the Cooperative societies with common interest. The subsidies will not be taken into account when calculating the dividends, accumulated in the company shares.

Dividends in the company shares: The probable subsidies will not be taken into account in the calculation of the dividends, accumulated in the company shares.

These dividends are restricted. The interest rate is equal to the average interest rate of the private bonds.

The Cooperative society with common interest cannot return and cannot increase the amount of the company capital, similarly to the other cooperative companies.

Italian and transnational partners

BULGARIA | FRANCE | FRANCE | GERMANY | GREAT BRITAIN | SPAIN

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Istruzione e cultura
Leonardo da Vinci