MSc Program
Renewable Energy in Central and Eastern Europe

Strategy for thermal, renewable energy supply in smaller output range for eastern Europe and the related demands on the boiler technology

A Master's Thesis submitted for the degree of
"Master of Science"

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Abstract

The aim of this work is a strategy, with which the countries in East-Europe can use their own renewable energies and so they will be more independent from fossil energy.

Due to the current situation reaching this aim is not possible.

The main biomass in form from wood-pellets will be exported to West-Europe on a high price level, the boiler technology is expensive and the purchasing power is low.

It is very important to know the energy market, the potentials from utilizable renewable energies and alternative renewable energies how agricultural biomass which is in this time not used. The important factor from the agricultural biomass is the net energy output per hectare land area and the associate expenditure with them.

The processing of the biomass is also an essential factor. The processing plants should be easy in operation and service. The investment costs must be clear.

The boiler technology must be developed and adapted for the special biomass crops.

For a high density from biomass boilers in a small region it is necessary, that the consumer gets a contracting model, so he has no investment, no risk with a new technology and the running costs are low and for a long time calculable.

Table of content

1. Lists

1.1. List of Figures

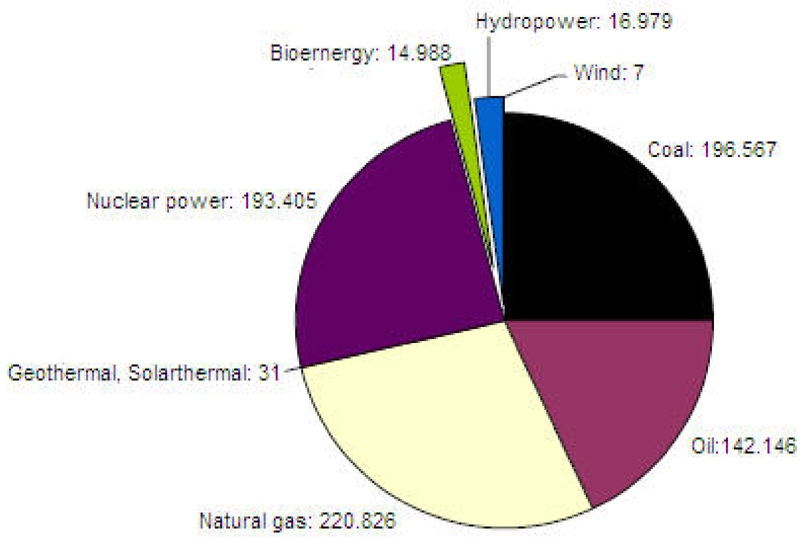
1.2. List of tables

2. Starting position

2.1. General overview on the example of Slovakia

The primary energy demand of Slovakia is strongly characterized by gas, crude oil, coal and nuclear power. About 90% of primary energy sources are imported. The only domestic primary energies, beside brown coal, are hydropower and biomass. They are playing a minor role till now (4.5%; see Fig 1).

Fig. 1 Primary energy demand Slovakia 2004



Source: ENERDATA database

In 2006 the average monthly wage was SKK 20'134 per month excluding social security contributions and the minimum monthly wage was SKK 7'600

2.1.1. Current situation

Total heat production in Slovakia is about 198.000 TJ.

Slovakia has a high developed district heating system (DH) as a result of the former state directed economy. Round 53.500 TJ (27%) are produced in district heating plants. About 62.500 TJ (32%) of heat are produced in plants with co-generation. 82.000TJ (41%) are produced in individual local boiler rooms.

The DH-system is weakened by rather low efficiency. "Lower energy efficiency is caused mainly by out-dated technologies used (boilers) and weak insulation of heat distribution system, which was built in the age of low energy costs.

The heat production is about 37 GJ/capita (in comparison Austria: 38.5 GJ/capita).

Individual heat supply includes single boiler rooms for multi dwelling houses, central heating for family houses and local boiler rooms for public buildings. In 2004 heat production in this sector was 82.000 TJ.

2.1.2. Development of heat market

In the past energy prices were very low. They didn´t match the costs for energy production. Energy was subsidised by state in different levels (primary energy production, distribution). The heaviest increase was in 2000 with 30% for natural gas and 25% for heat in one year period. The next year the prize rose for natural gas for 15% and the second following year for 9%. The increase of energy hits especially low income social stratums. Energy costs reaching up to 25% of their income.

2.1.2.1. Natural gas

It is assumed, that consumption in for the residential sector is slightly increasing or even constant due to enormous rising natural gas prices.

Despite the dense supply system Slovakia is depending on one foreign supplier: 97% are imported from the Russian Federation.

There is a slightly increase in total consumption anticipated: from 6.5 billion m3 in 2005 up to 7.1 billion m3 in 2030.

2.1.2.2. Coal

Coal plays an important role in CHP for heating. 80% of all lignite consumption is domestic produced. 20% of brown coal and 100% of black coal is imported.

Coal industry is decreasing and this trend will continue strongly due to the requirements for fulfilment the CO2 reduction programs and carbon quota. It is more and more substituted by natural gas.

Coal is, beside RES, the only primary energy source in Slovakia. Domestic brown coal production is a strong subsidised energy carrier. Without state subsidies coal cannot compete with imported coal or natural gas.

2.1.2.3. Renewable energy

Renewable energy sources (RES) are not developed very well currently but has a great potential for short and long term future. RES have a strong perspective because they have the only sustainable domestic energy with a sufficient amount to have significant impact to storable energy mix.

A lot of measures have to be implemented to increase the share of RES on final energy consumption. The economic potential for heat (as a measured value for policy success) is about 37% of technical potential and market potential is about 13%.

Biomass is the main renewable source for heat production. Currently about 2.5% of energy demand is produced by biomass.

2.1.2.4. Structure of housing

This sector of residential buildings is the main focus for the utilization of pellets for room heating purposes. Normally smaller power capacities (up to 200 kW) are utilized. This meets the utilizable range in pellets heating systems.

Family houses	792.555	827.886
Multi dwelling buildings	61.855	869.472
Others	7.864	16.054
Total	862.274	1.713.412

Table 1 Permanent occupied houses by type of building, 2001

Source: Population and Housing Census, Statistical Office of the Slovak Republic

Single family houses are dominating in rural areas. They are marked by low- to middle- income level. This crosses with the high investment costs for pellets heating or with modern heating purposes in general.

2.2. Potentials of renewable energy

For a short description we have to distinguish four steps of potentials:

Technical Potential

Is the total potential of existing renewable energy resources which can be exploited by today existing technologies. It is not limited by any barriers.

Utilizable Potential

Is the technical potential reduced by political and legislative barriers, social and environmental constraints and the lack of infrastructure. The following numbers give an example regarding the utilizable potential.

Economical Potential

Is the utilizable potential within economic frame conditions like investment costs, costs for operation and maintenance, discount rates. Economic potential is about 26,000 TJ in 2012[1].

Market Potential

It is the economical potential within the boundaries of market requirement like investment risks and expected benefits. It is including the willingness for the investment.

In 2012 the market potential will be about 9,000 TJ or 34% of economical potential. This is resulted by unsafe legal situation and very high investment risks. Market potential is much lower than economic potential. Significant policy measures, especially in legislation are needed to realize a higher percentage.

[1] www.energyagency.at/enercee/sk/supplybycarrier.htm#h4

On the basis of existing analyses the total potential is 87.700 TJ/year. Considering the current exploitation there is an additional available potential of 73.000 TJ/year.

Geothermal	22.680	1.224	21.456
Wind	2.178	0	2.178
Solar	18.720	25	18.695
Small Hydro	3.722	727	2.995
Biomass	40.453	12.683	27.770
Total	87.754	14.659	73.094

Table 2 Technical and available potential of RES in SK, in TJ

Source: Ministry of Economy of Slovak Republic, 2002

In Slovakia renewable energy is not utilized very well. In 2002 only 1.6% of total primary energy consumption is represented by renewable energy sources (except large hydro power).[2] For comparison: Slovak´s yearly energy consumption is about 800 PJ.

[2] www.energyagency.at/enercee/sk/supplybycarrier.htm#h4

Table 3 Potential for renewable energy sources in Slovakia, in TJ, in 2012

	Available potential		Economic potential		Market potential	
	heat	electricity	heat	electricity	heat	electricity
Geothermal	20.384	1.073	7.920	504	4.230	125
Wind	0	2.178	0	505	0	150
Solar	16.321	2.374	4.250	210	1.260	10
Small Hydro	0	2.995	0	749	0	299
Biomass	23.606	4.164	10.058	1.810	2.412	520
Total	60.311	12.784	22.228	3.778	7.902	1.104
Grand total	73.095		26.006		9.006	

Table 3 Potential for renewable energy sources in Slovakia, in TJ, in 2012

Source: NEES Slovakia 2002

The table above shows the distribution of the different types of potentials as a forecast for 2012.

The gap between Economic and Market potential for biomass is the highest (market potential is only one fourth of economic potential) and biomass has the highest economic potential (about 40% of RES). The current utilization is on a quite low level.

2.2.1. Biomass

Biomass has the highest technical potential of RES with an energy value of 40.500 TJ/year. Available Potential is about 27.700 TJ/year. This data assumes no other use for biomass as for energy purposes.

Biomass has the highest available as well as economical and market potential of all RES in Slovakia (46% of all RES), especially solid biomass for heat production in form of wood logs, wood chips, pellets and straw as an agricultural by product.

	Technical potential	Current exploitation	Available potential
Biomass	40.453	12.683	27.770
thereof: Forest wood	6.710	1.778	34.932
Wooden and multiannual energy plants	6.613	-	6.613
Wood processing industry	15.862	9.479	6.365
Agricultural biomass	8.359	216	8.143
sewage sludge	828	47	781
Domestic waste	2.081	1.145	936

Table 4 Potential of different biomass resources, in TJ

Source: Ministry of Economy of the Slovak Republic, 2002

Considering the prevailing conditions in the Slovak Republic, biomass can be utilized as wood from forest and as residuals from wood processing industry (also paper and pulp industry), agricultural energy plants and residuals and waste from food industry

2.2.2. Present biomass utilization for heat production

	2002	2003	2004	2010	2015
Biomass	474	643	1.354	25.000	37.000
Biogas	1	0	0	2.000	4.000
Geothermal	159	139	144	200	1.000
Solar	36	40	45	300	1.000
Total	670	822	1.543	27.500	43.000

Table 5 Heat production from RES 2002-2004 and targets for 2010 and 2015, in TJ

Source: Strategy for higher utilization of RES in SR, Ministry of Economy of SR, 2006

Since the last three years biomass utilization is increasing due to strong increasing of natural gas price and energy prizes in general. This is a demand side driven phenomenon. This trend will be continued.

This statistics doesn´t include the utilization of biomass in households, especially single family houses in rural areas, due to statistical insufficiency. Furthermore is much more biomass utilized in paper and pulp industry. They use the residuals and by products for their own energy purposes. This energy amount isn´t included in the table above, too.

It is expected, that the number of biomass heating plants will increase. They will use more locally wood chips even though there are some quality problems with moisture contents. The co-firing of Pellets is an opportunity to reduce this problem.

2.2.3. Resources from wood processing industry

Pellets and Briquettes are commonly produced with sawmill by-products. Producing pellets direct from waste wood from forestry is more expensive because of the additional process of milling the wood.

Current only sawmill-based pellets production is relevant.

2.2.4. Current biomass potential and production of pellets.

The main raw material resource for pellets production is from wood processing industry, especially saw mills.

About 35 % of supplied round wood are by-products such as saw dust, bark and wood residues.

Current production rate of pellets and briquettes is about 75.000 tons/year. Under present forest production rates there is an additional pellets potential of at least 70.000 tons.

2.2.5. Potential, based on timber felling, outlook

For a long term review an annual felling of 6 million solid cubic meters is expected. This accords a potential of about 3.8 PJ. Analogue to the calculations above, an amount of 220.000 tons pellets from wood processing industry can be expected.

2.3. Basics of the European pellet market

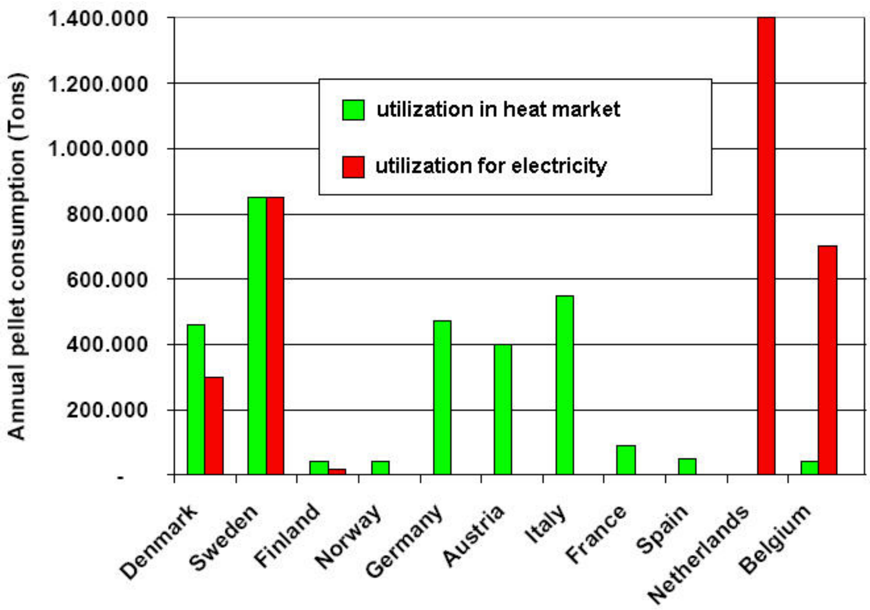
Pellets for residential heating are used for single room stoves (mainly Italy and Mediterranean countries, delivery in sacks) and central boilers for single family houses with capacities up to 50 kW (main markets in Austria, Germany) with bulk delivery. Heat market in Europe is about 3.000.000 tons of pellet. There are higher prices (180 – 200 €/tonne bulk) but is more volatile.

In the Western European countries mainly Austria, Germany and Italy pellets firing systems are a high developed and a well accepted heat supply.

The whole pellet market is rapidly growing. Several kinds of demand, subsidy schemes to meet obligations of EU renewable energy policies, climate protection targets and rising environmental awareness, ensuring the security of supply and a well developed technology with high convenience are the drivers for an encouraging expansion.

The Western and Central European pellet market is an emerging market with all its uncertainty and volatility characteristics. There are some problems to establish a well balanced growth between demand and supply side. A shortage in production in comparison to the rising demand led to the noted price increase in winter 2006/2007. The price instability caused a loss of confidence and a non decision for pellets fired systems. Boiler sales dropped about 50%. Price stability and supply security are the key factors to get back the consumer´s confidence and for a continuing growth.

Fig. 2 Pellets demand in Europe 2006



source: Rakos, propellets Austria 2007

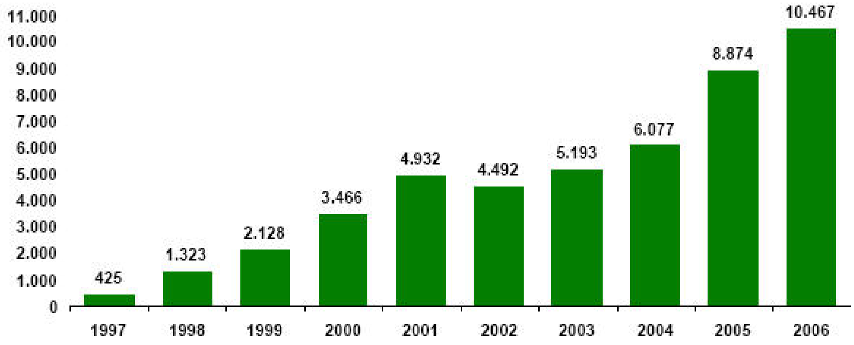
As seen in 2007 the volatility can be reduced by higher and a more widespread production. It is important to increase the number of producers. On the other hand there is a certain danger of oversupply. This can be avoided by creating new markets both in geographic meaning and in demand (pellets for capacity up to 200 kW: e.g. public buildings, micro grids, multi storey houses).

2.3.1. Country portraits

2.3.1.1. Austria

The utilization of pellet central heating boilers is strong increasing over the last 10 years.

Fig. 3 Yearly installed small scale biomass boilers

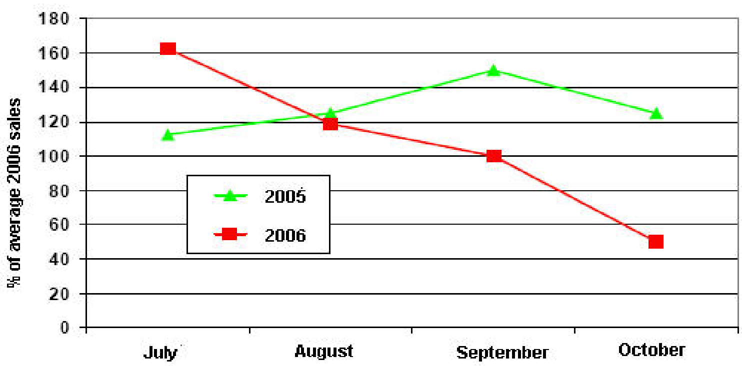


1999	2000	2001	2002	2003	2004	2005	2006
38.396	59.993	88.928	84.323	100.035	118.327	170.991	202.181

source: NÖ Landeslandwirtschaftskammer, 2007

There was a high increase of the utilization of pellet central heating boilers in 2005 with not less than 46% in one year. The growth rate of 18% in 2006 was contrary to the market considerably lower. This was due to a sharp increasing of pellets consumer prices and delivery problems in some areas. Many of interested customers decided then not to install a pellets heating system. It is expected that the boiler market is stabilised on a high level due to a constant and improved delivery logistics. In the last two years three times more biomass boilers than oil heated boilers were new installed. This trend will continue.

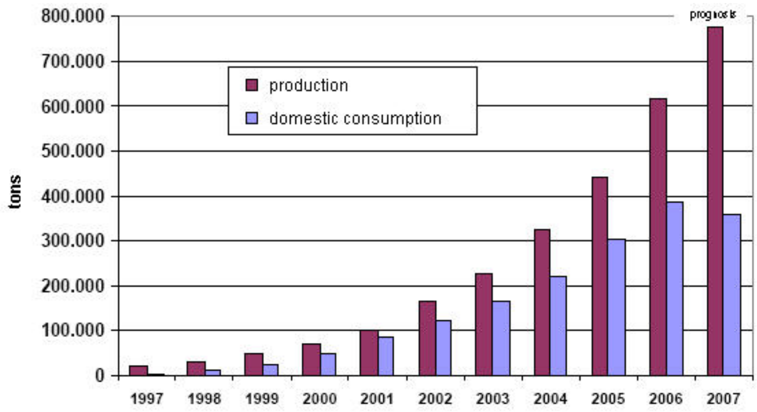
Fig. 4 Development of pellet boiler sales in Austria



Source: pro pellets Austria, 2007

In the end of 2006 there was a total number of 47.000 boilers installed.[3] The average capacity is 19 kW. If we assume a fuel demand of 400 kg per kW capacity the total pellets consumption in Austria is about 360.000 tons per year. For 2007 an additional gain of approx. 10.000 new boilers (with an additional demand of 80.000 tons) is expected.

Fig. 5 Austrian pellets production and domestic consumption



Source: pro pellets Austria, 2007

As the figure shows, production is continuously rising due to new planned and constructed sites whereas domestic consumption is stagnating. This is due to the strongly rising of retail prices in 2006/2007 and linked with that a massive drop of consumer´s confidence. This can be seen on the sales of pellets boilers as an indicator for pellet market development, too. But pellet market has still a positive image. There are some subsidies on country and municipality level and the retail prices dropped down to the level of 2005/2006. The market will recreate and will come back to an expanding but more moderate growth.

[3] Niederösterreichische Landes-Landwirtschaftskammer (2007): Biomasse – Heizungserhebung 2006, St. Pölten

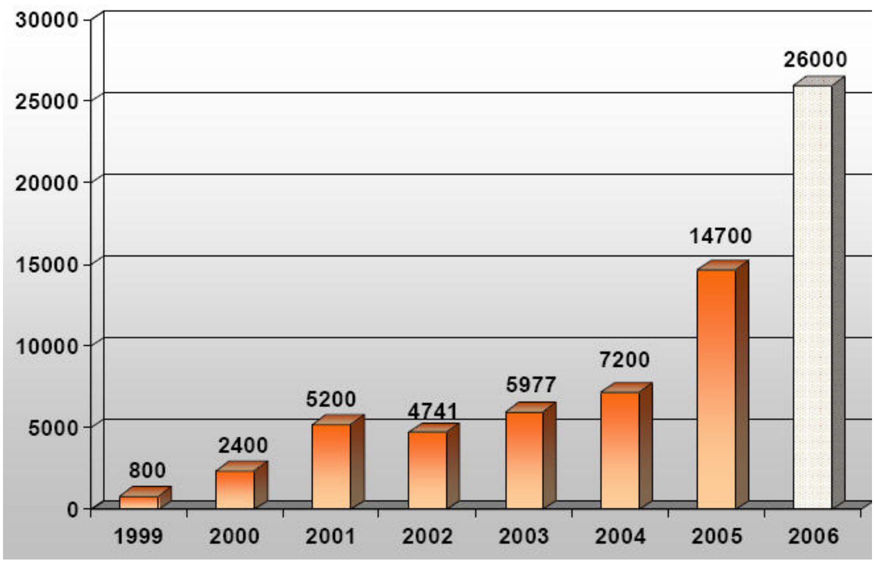
A rough estimation for pellets demand shows a forecast for production of approx. 1.000.000 tons/year as an upper limit.

It is expected that an anticipated higher domestic consumption will be coupled with an analogue reduction of exports. The demand level of raw materials for pellets production will be on same level.[4]

2.3.1.2. Germany

Beside Austria Germany is the most important market for high quality pellets central heating in residential houses. The market had an enormous growth in the past years.

Fig. 6 Boiler sales in Germany



Source: www.depv.de

There are about 70.000 single boilers and stoves installed (0,2% of households, 3,2% of new installed boilers).

4 www.timber_online.net, 09/2007.

Germany is a strong emerging market with a high potential in residential and public sector. Main imports are from Austria (approx. 30% of demand), from Poland and Czech Republic. Exports are mostly to Italy.

2.3.1.3. Italy

Italian pellet market is based on firing in single wood stoves. In 2006 200.000 stoves were sold. In 2007 the sales drops to 160.000 stoves.

90% of consumption is retailed in sacks. The demand for 2007 is estimated with 700.000 tons. About 200,000 – 300,000 tons have to be imported, mainly from Austria and Germany. The Italian market admires high quality pellets as described in ÖNORM M7135.

2.3.1.4. France

France isn´t a high developed market but has a high potential for future. France has installed a promising subsidy system with reduced VAT for wood fuels and district heat from biomass boilers (5.5% instead of 19.5%) and tax refunding for investment costs. In 2007 started a qualification scheme for installers and several marketing and promotion activities for renewable energies.

There are about 200.000 stoves installed. Boiler sales increased from 115 in 2003 to 5.800 in 2006.[5] Pellets production is about 90.000 tons.

2.3.1.5. Scandinavian and Benelux Countries

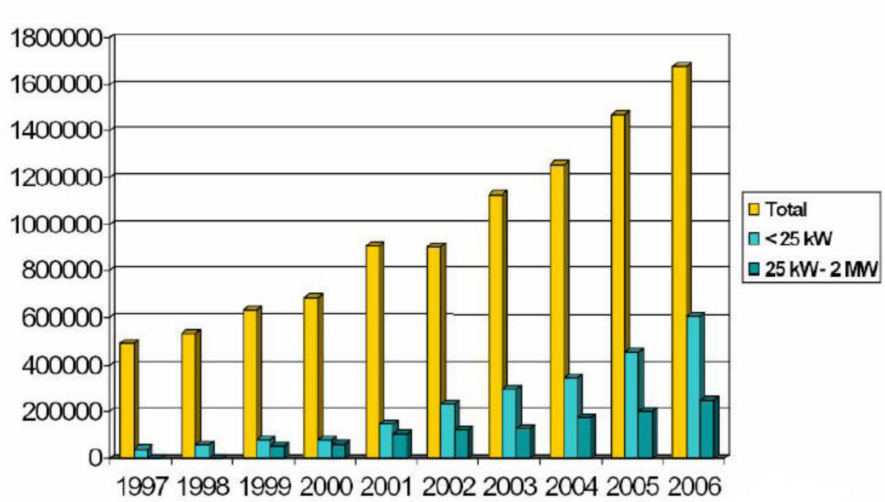
In the Scandinavian and Benelux countries pellets are used mostly in CHP plants for electricity production. The total demand is about 3.400.000 tons of pellets.

The Netherlands imported 690.000 tons of solid biomass, mostly pellets. There were imported from Austria but also from Scandinavia and overseas. Single boiler firing is

[5] Rakos, C. (2007): Recent developments in European pellets market

not developed very well. In the future the import rate of biomass has to be enhanced to meet the obligations of EU renewable energy targets.

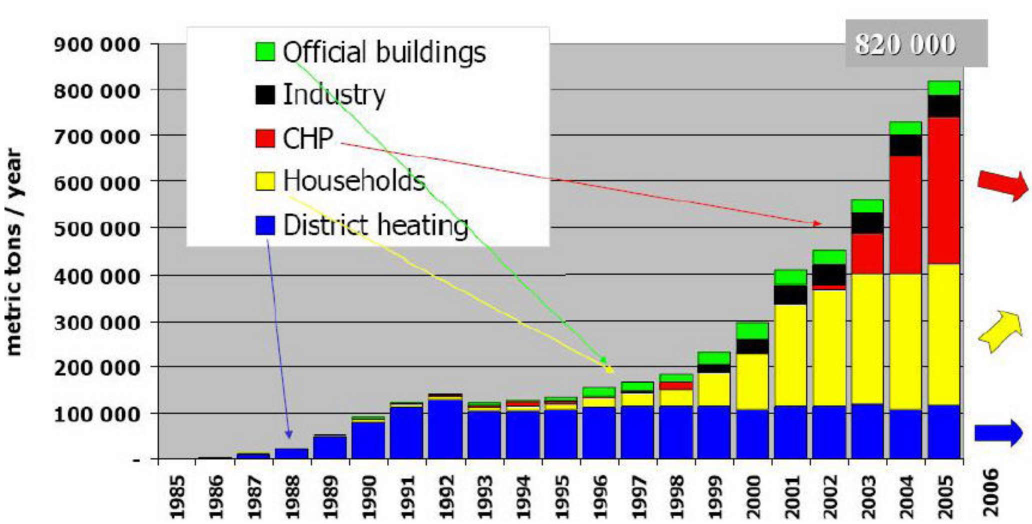
Fig. 7 Pellets sales in Sweden



Source: Rakos, propellets Austria, 2007

Denmark has a widespread consumption in CHP plants and heating for public buildings and residential buildings.

Fig. 8 Pellets market in Denmark



Source, Jonas Dahl, Force, 2007

3. Market analysis for biomass heating systems

3.1. Project design

The conditions of the plan consists of two main pillars.

1. Build up a domestic market with the concept of an integrated energy service. It is including sales of pellet boiler and pellet fuels.

2. No export of pellets in the developed market in Western Europe. This is only possible, when the pellets produced in Eastern Europe are not compatible to traditional Western Europe boiler systems.

3.1.1. Prices for wood biomass utilization

kind of biomass	**Current average selling price direct from supplier (in €/ton)**
Pellets consumer price	130 -154 (excl. VAT)
Briquettes consumer price	73 -118 (excl. VAT)
Wood chips wet from forest	20 - 24 (ex. VAT, inc. transport)
Fire wood from forestation	28 - 50
Sawdust from wood processing	14,50 - 17

Table 6 Prices of biomass raw materials and consumer prices for pellets

Source: Ministry of Agriculture of Slovak Republic, 2006

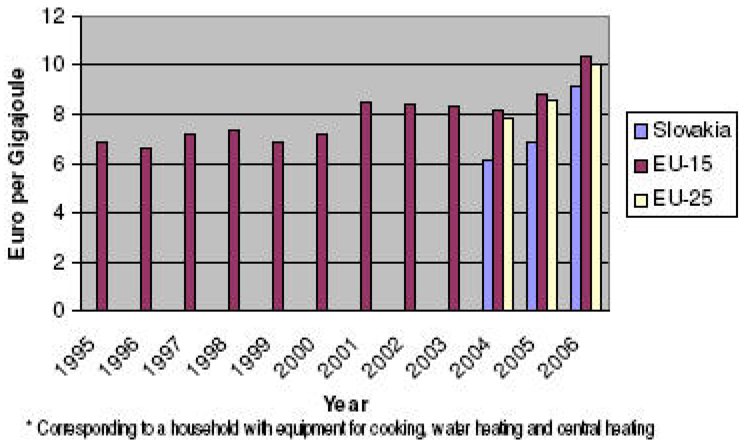
Current pellets prices for customers is about 160-190 €/to including VAT for a household quantity of 5 to. This is not an attractive price for the consumers in Eastern Europe.

The market price of pellets must approximately be lowered by 30% to 40% down.

3.1.2. Compared energy prices in Slovakia

There is an increasing interest in alternative heating systems with rising energy prices of fossil fuels. Since 2004 the gas price for households has increased for 49% and for industrial users for 57%.[6]

Fig. 9 Household gas prices (excl. tax)



Source: Eurostat, 2007

Comparison of gas and pellets consumer prices (own calculation, various sources):

Current market price:

energy prices in €/GJ	
natural gas	9,20
pellets	8,80

Source: own calculation, lecture notes Dounrava et al, AEA

3.1.3. Market barriers for introducing pellets heating

[6] Eurostat, 2007: http://epp.eurostat.ec.europa.eu

- Biomass utilization is quite expensive due to high investment costs, especially for pellets boilers.
- Lack of awareness for this kind of heat production.
- Consumers distrust to availability of technology and reliability of pellets supply. There is lack of confidence and renewable energy is representing higher risks in investing and supplying.
- No domestic boiler producers for pellet boilers.
- Lack of marketing and market preparation. Lack of coordination between pellets producers, boiler manufacturers and installers.
- Lack of experience and “know how” among installers, heating technicians, planers, administration on biomass combustion.

3.1.3.1. Barriers for biomass/pellets utilization

The barriers for a higher utilisation of biomass for heating purposes are:

- Little knowledge of consumers, plumbers and chimney sweepers.
- Not very high developed boiler industry for lower power capacities, therefore no market drivers for pushing the alternative firing materials.
- No tradition of high quality wood firing therefore high sceptically consumers
- Higher investment costs for biomass heating facilities (especially pellets firing).
- Missing equity capital for establishing new heating facilities.
- Lack of effective financial support for small scale units.

3.1.4. Marketing Strategy

To negotiate the market barriers on demand side, it is projected to establish a whole chain of heat service. This includes the installation and maintenance of pellet boilers and its equipments as well as the production and the contract based delivery of pellets for these installations.

Customers have to purchase for the service. Investment and maintenance is on the responsibility of the contractor. For a successful business operation it is important to ensure the supply chain of pellets delivery as well as good constructed and maintained boilers. One side could not work without the other.

To meet the requirements of the business there has to be a cost effective heating system over lifetime. The customers are not familiar with modern biomass technology. The business must offer a full service. We do not only deliver biomass fuels, but also boilers and installation equipment (in cooperation with local and well plumbers, trained by our company). The contracting model guarantees the delivery of heat from renewable sources with stipulated prices over a defined duration. After an arranged time the costumer will be the owner of the boilersystem.

3.2. Efficient energy use in buildings and saving potential

Basic figures to the heat supply in Slovakia are already given in chapter 3.2. In addition to this we will focus here on the figures relevant to efficiency and possible market for renovation.

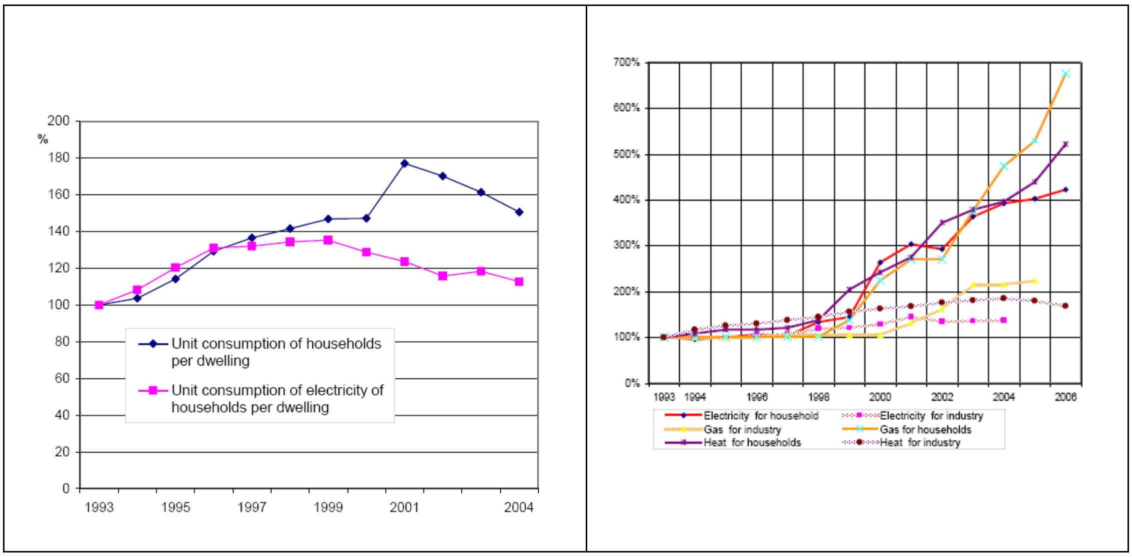
Description	Value
Average floor surface per dwelling	83.9 m^2
Average energy consumption (heat and hot water)	170 $kWh/m^2/a$
Average Energy consumption per dwelling per year	14.26 MWh/a = 51.34 GJ/a
Number of dwellings from table 3 in chapter 3.2	1.713.412

Table 7 Energy data for housings in Slovakia

Source:ECN WP2 overview report for the InoFin project, Feb. 2007

The actual energy consumption of new built premises build according to latest standards used in Western Europe is about 50 $kWh/m^2/a$

Fig. 10 Household energy consumption and development of price



Source: SIEA report, Energy efficiency policies and measures in Slovakia 2006, June 2007

3.3. Summary of the overview

Pellets are energy with simply handling for single family houses in rural areas.

In Slovakia are about 790.000 single family houses.

Energy costs reach up to 25% of the income from the Slovakian people.

The average monthly wage was SKK 20.123 (€ 600) per month, the minimum monthly wage was SKK 7.600 (€ 230).

About 90% of primary energy sources are imported.

Natural gas is imported from the Russian Federation to 97%.

Since 2004 the gas price for households has increased for 49% and for industrial users for 57%.[7]

The available potential from biomass is 27.000 TJ in Slovakia.

Out of this potential there are 8.143 TJ of agricultural biomass.

The current production rate of pellets in Slovakia is 75.000 tons/year.

88% from this rate are exported to Western Europe.

The volume of the heat market in Western Europe consists of about 3.000.000 tons of pellet / year.

The price is 180 – 200 €/ton bulk for woodpellets in the Western European Market.

The central boilers for single family houses have capacities up to 50 kW[8].

(Average capacity is 19 KW).

The growth rate of pellet boiler in Western Europe can be more than 40%.

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[7] Eurostat, 2007: http://epp.eurostat.ec.europa.eu

[8] ACCESS Project: Accelerated Penetration of Small Scale Biomass and Solar Technologies. WP2 – RET Market Analysis,

4.Primary energy Earning from agricultural biomass

4.1. Summary

The relationship between energy input and energy output is an important consideration for every means of energy production. This chapter compares the possible primary energy earnings from biomass with the necessary energy input to cultivate them.

Data is not shown for each type of biomass. On the one hand they are not yet available, on the other hand this document should mainly show the possible dimensions of energy earnings. All data are related to land area (ha) and per year (a). Cursive written data is estimated.

Energy earnings by biomass are possible up to 350 [GJ/ha a] and are dependent of the type of plant. The necessary energy input is up to about 30 [GJ/ha a]. The table below shows the summaries of energy output and energy inputs for cultivation.

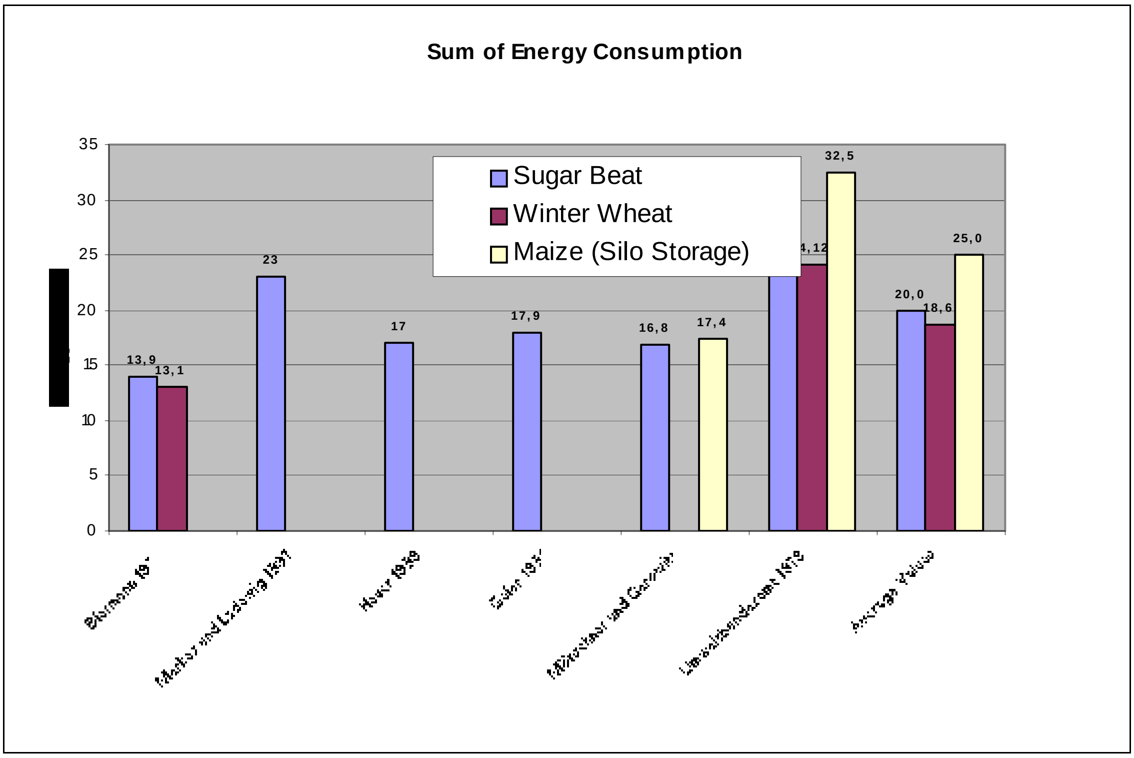
Plant	Energy Output	Energy Input					Net Energy Output
		Seeds	Fertilizer	Pesticide	Handling	Sum	
	[GJ/ha a]	[GJ/ha a]	[GJ/ha a]	[GJ/ha a]	[GJ/ha a]	[GJ/ha a]	[GJ/ha a]
Wheat	102,6	0,63	11,43	1,0	9,0	22,06	98,6
Rye	88,5	0,26	7,48	0,6	6,0	14,34	74
Triticale	85	0,44	8,49	0,6	6,5	16,03	69
Maize	123,9	0,56	12,89	1,6	4,9	19,95	104
Rape	77,9	0,14	11,68	1,1	9,9	22,82	55
Sunflower	62,1	*0,14*	12,37	0,2	6,7	19,41	42,5
Miscanthus	352,0	*0,10*	4,69	1,0	10,54	16,33	336
Fast growing plants	180,0	*0,10*	4,20	0,5	*3,0*	7,8	172

Table 8 Net energy output from plants

With Miscanthus the maximum net energy output of 336 [GJ/ha a] is shown.

Most of the energy inputs are needed for fertilizing and handling. Handling includes mostly fuel and further energy for machines and logistic. For a cross check and a rough estimation data from other sources and average values of the different data sources are shown in the table below.

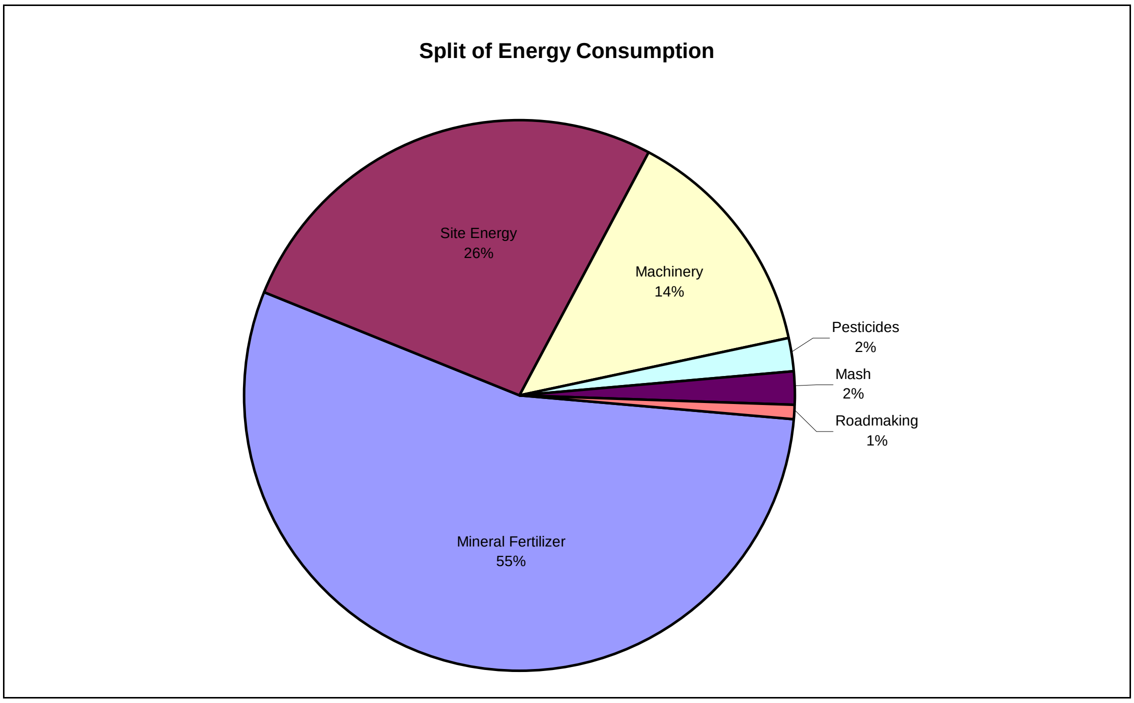
Fig. 11 Sum of energy consumption for cultivation



Additional a split of energy consumption from the Austrian ministry of agriculture is shown in picture 12[9], which confirms this fact. The "Site Energy" mentioned in this picture consists mainly of diesel fuel and electrical power.

9 Energieflüsse in der Landwirtschaft 2002,Landwirtschaftsministerium Austria

Fig. 12 Split of energy consumption for cultivation



An aim should be to grow plants with a minimum of fertilization and irrigation and adhering to biological processes. In this way we can markedly improve the energy balance, reduce production costs, and avoid detrimental side effects, such as increased chorine content caused by the use of stalk-stunting chemicals.

It is important to consider not only the yield potential of the crop, but also the compatibility of the crop with the climate, topography and soil conditions. Crop rotation is also important. Grain, oilseed and maize crops could make a good combination here.

The planting of fast growing forests for fire wood, meaning mainly poplar and willow, is also a viable alternative.

To achieve the optimum return it is essential to seek continuous refinements for the preparation and processing of the material.

An interesting consideration is the use of regenerating crops, such as Miscanthus (elephant grass), a perennial grass, which can be harvested year after year without replanting. One advantage of these so-called C4 crops is that they offer a high yield of energy with minimum application of fertilizers.

4.2.Crop of biomass

Following table shows the primary energy earnings from certain plants. In this table only whole plants are considered. The primary energy is calculated by the crop (dry matter) multiplied with the lower heating value.

Plant	Crop[10]	Lower Heating Value[11]	Energy Output
	[kg/ha a]	[MJ/kg]	[GJ/ha a]
Wheat	6.000	17,1	102,6
Rye	5.000	17,7	88,5
Triticale	5.000	17,0	85
Maize	7.000	17,7	123,9
Rape	3.800	20,5	77,9
Sunflower	3.200	19,4	62,1
Miscanthus	20.000	17,6	352,0
Fast growing plants	10.000	18,0	180,0

Table 9 Primary energy output from plants

10 M.Kaltschmitt; H.Hartmann (Hrsg.), Energie aus Biomasse (Springer 2001): pp. 57 – 93.
11 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf

The most crop is shown for Miscanthus with 352 [GJ/ha a]. Other sources show slightly different values. Biological test for maize used in biogas plants show crops up to 23050 kg/ha a[12]. So in future we can expect up to 15% higher values. Of course climatic and soil conditions have a main effect to the crop.

4.2.1. Energy input for seeds

Following table shows the energy input for seeds. The values in the literature for the energy input are related to 1 kg of seeds and must be therefore multiplied with the needed amount of seeds per hectare.

	Energy Output per ha	**Amount of Seeds[13]**	**Energy Input per kg Seeds[14]**	**Energy Input per hectare**
Plant	**[GJ/ha a]**	**[kg/ha a]**	**[MJ/kg]**	**[GJ/ha a]**
Wheat	102,6	180,0	3,5	0,63
Rye	88,5	87,5	3,0	0,26
Triticale	85	126	3,5	0,44
Maize	123,9	40	14,0	0,56
Rape	77,9	10	13,5	0,14
Sunflower	62,1			*0,14*
Miscanthus	352,0			*0,10*
Fast growing plants	180,0			*0,10*

Table 10: Energy input for seeds

12 Die Saat; Biogas Sortenliste
13 M.Kaltschmitt; H.Hartmann (Hrsg.), Energie aus Biomasse (Springer 2001): pp. 57 – 93. Sometimes only the number of corns per square meter are mentioned. This number must be multiplied with the thousand corn weight of the plant to get the necessary weight of seeds per square meter.
14 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf

4.2.2. Energy input for fertilizer

The application of artificial fertilizer represents a main input for agricultural sources. Following data were found and assumed for the production of fertilizers[15]:

For Nitrogen (N) production an energy input of about 59 MJ7kg is necessary. The theoretical minimum would be 32 MJ/kg[16]. For Phosphor (P) as P_2O_5 17 MJ/kg, for Kalium (K) as K_2O 10 MJ/kg and for Calcium (Ca) 3 MJ/kg are needed. Literature[17] states also lower values for Phosphor with 6 MJ/kg and for Kalium with 3 MJ/kg. With the lower values the energy demand for fertilization may be halved in the near future.

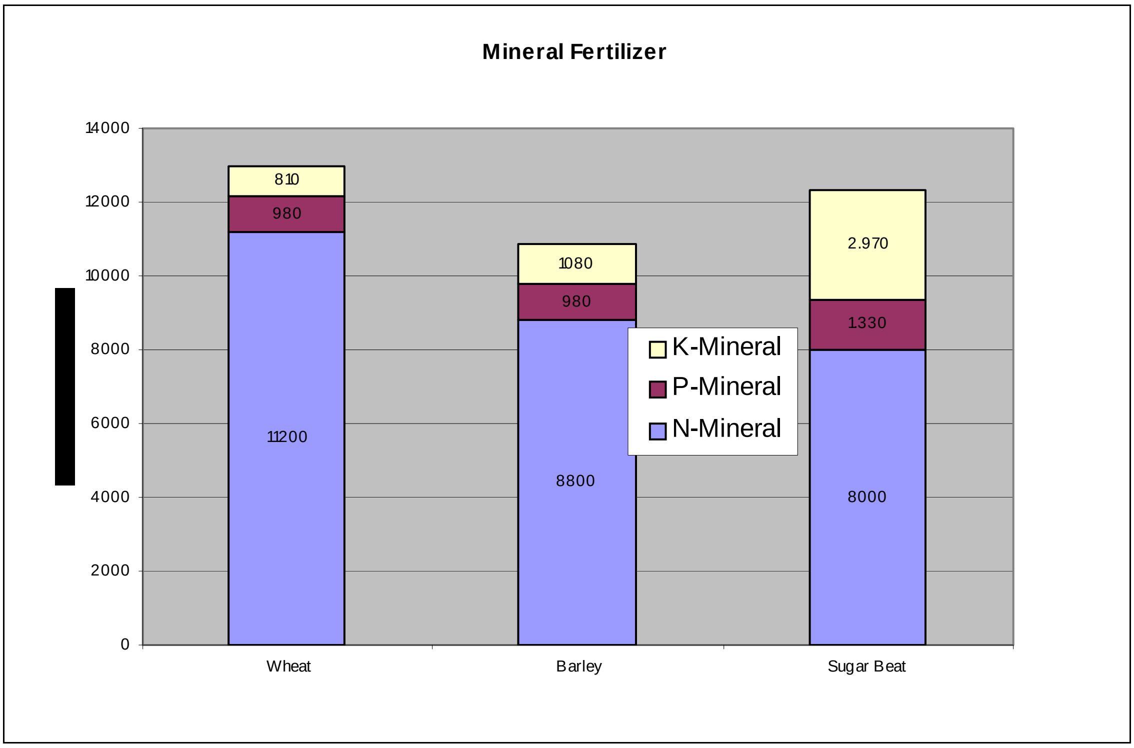
	Energy Output per ha	[Fertilizer demand in kg/ha a][18]					Energy Input per hectare
Plant	[GJ/ha a]	N	P	K	C	Mg	[GJ/ha a]
Wheat	102,6	171	28	82	14	5	11,43
Rye	88,5	107	20	77	18	10	7,48
Triticale	85	120	30	85	16	9	8,49
Maize	123,9	180	45	150		30	12,89
Rape	77,9	170	34	84	78	16	11,68
Sunflower	62,1	156	38	252		36	12,37
Miscanthus	352,0	60	9	100			4,69
Fast growing plants	180,0	60	15	35	18	3	4,20

Table 11: Energy input for fertilizing

15 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf
16 Industrieverband AGRAR, 60329 Frankfurt; www.iva.de: IVA_Arbeitsblatt_2
17 Bundesarbeitskreis Düngung; „Phosphat und Kali, Bausteine nachhaltiger Ertragsbildung“
18 M.Kaltschmitt; H.Hartmann (Hrsg.), Energie aus Biomasse (Springer 2001): pp. 57 – 93

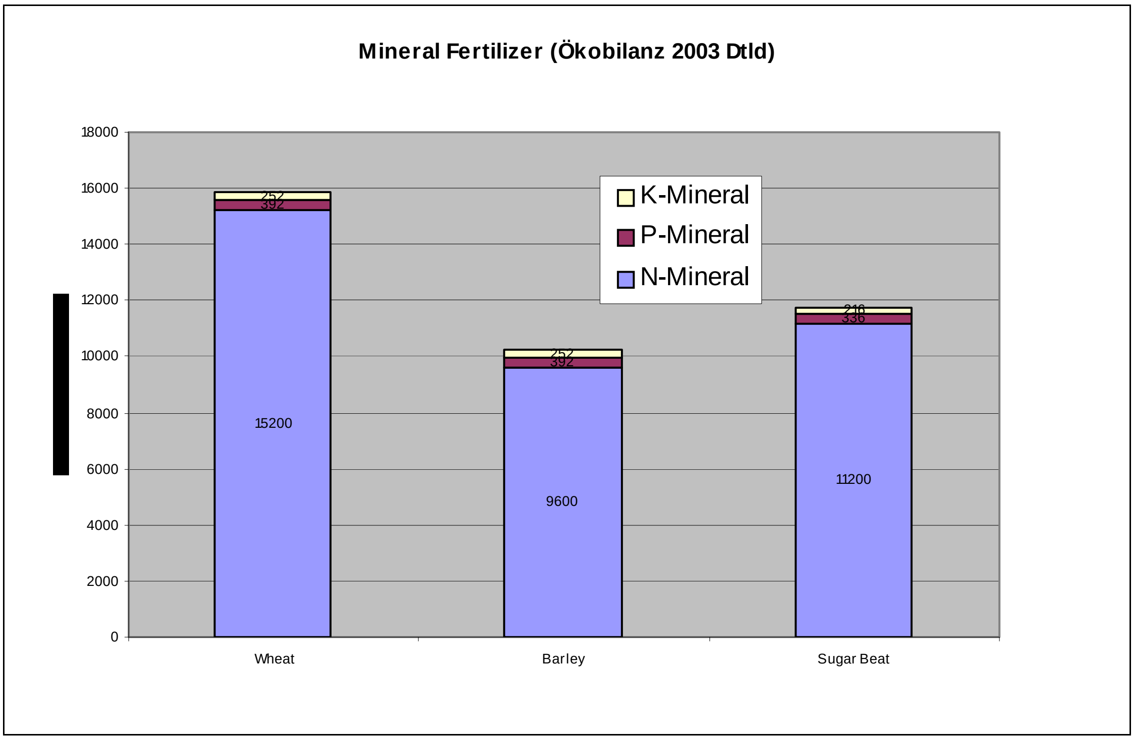
The amount of fertilizer varies according the climatic and soil conditions. To get a impression about the variations of data from different sources, some figures about energy consumption per year for fertilizing are shown in the following pictures.

Fig. 13 Energy consumption for mineral fertilizer (Calciumagro 2005)[19]



19 Calciumagro 2005; http://www.calciumagro.ch/uploads/Düngersortiment_d_16.03.2005.pdf

Fig. 14 Energy consumption for mineral fertilizer (Ökobilanz 2003 Dtld)[20]



4.2.3. Energy input for pesticides

Variations are shown in the application of insecticides, but, as the energy input into insecticide production is relatively small, the effect on the overall equation is not so significant. In the relevant studies the contribution due to insecticide production was estimated at 2% of the overall energy consumption for cultivation. Following table shows a rough estimation[21] with a specific energy consumption for pesticides within 0,05 and 0,1 MJ per kg dry matter.

20 Ökobilanz 2003 Dtld
21 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf

Plant	Energy Output per ha [GJ/ha]	Crop of dry Biomass[22] [kg/ha]	Energy Input Pesticides[23] [MJ/kg]	Energy Input per hectare [GJ/ha]
Wheat	102,6	6.000	0,05	1,0
Rye	88,5	5.000	0,05	0,6
Triticale	85	5.000	0,05	0,6
Maize	123,9	7.000	0,1	1,6
Rape	77,9	3.800	0,1	1,1
Sunflower	62,1	3.200	0,05	0,2
Miscanthus	352,0	20.000	0,05	1,0
Fast growing plants	180,0	10.000	0,05	0,5

Table 12: Energy input for pesticides

4.2.4. Energy input for handling

Handling includes mostly fuel and further energy for machines and logistics. Following table shows the demand for handling with reference to the plant. The listed specific energy demand is related to the grains.

22 M.Kaltschmitt; H.Hartmann (Hrsg.), Energie aus Biomasse (Springer 2001): pp. 57 – 93.
23 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf

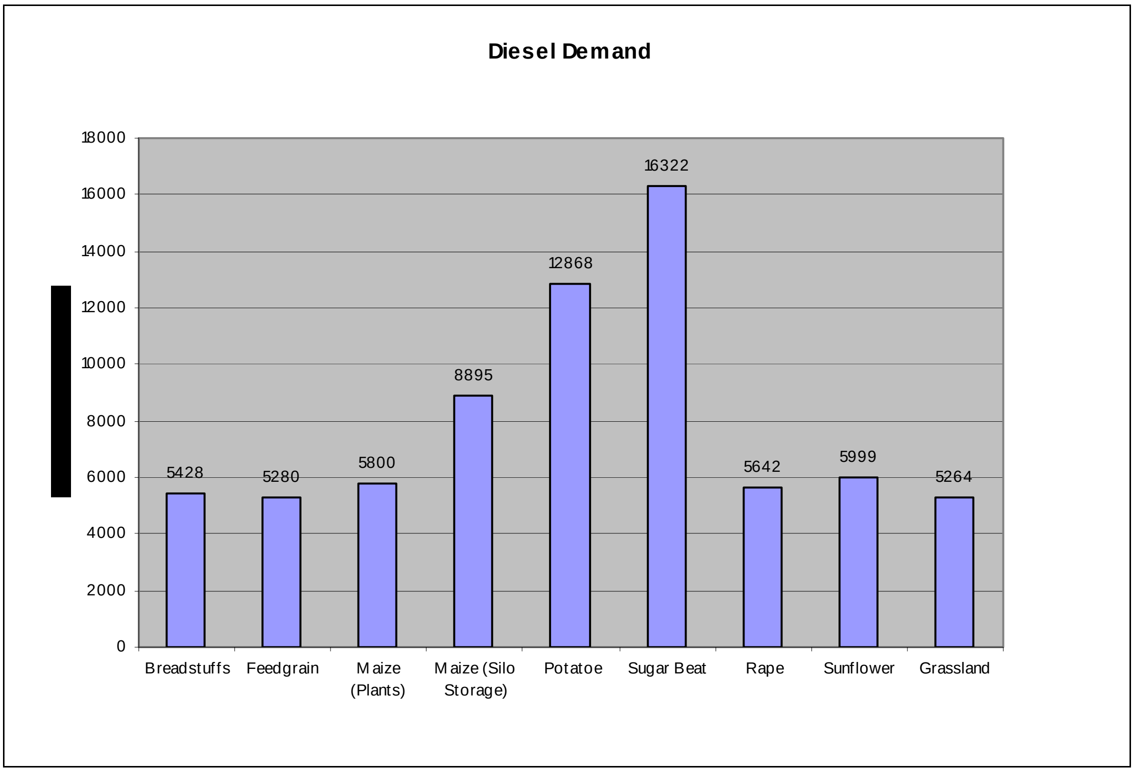
Plant	Energy Output per ha [GJ/ha]	Crop of dry Biomass[24] (Grain) [kg/ha a]	Energy Input Handling[25] [MJ/kg]	Energy Input per hectare [GJ/ha a]
Wheat	102,6	6.000	1,5	9,0
Rye	88,5	5.000	1,2	6,0
Triticale	85	5.000	*1,3*	6,5
Maize	123,9	7.000	0,7	4,9
Rape	77,9	3.800	2,6	9,9
Sunflower	62,1	3.200	2,1	6,7
Miscanthus	352,0	20.000		10,54[26]
Fast growing plants	180,0	10.000		*3,0*

Table 13: Energy input for handling

The significant part of handling consists of diesel fuel. The following table from a different source shows the diesel fuel consumption for different plants. The data differs a little from the table above, but is generally in the same range.

24 M.Kaltschmitt; H.Hartmann (Hrsg.), Energie aus Biomasse (Springer 2001): pp. 57 – 93.
25 Schweizer Zentrum für Ökoinventare; www.lcainfo.ch/DF/DF20/DF20-Agric-d-FALFAT.pdf
26 Dr. Ralf Pude;Universität Bonn; “Miscanthus, Anbauerfahrung und Nutzung”; www.duesse.de/znr/veranstaltungen/weg_vom_oel_2007/pude.pdf

Fig. 15 Energy consumption for mineral fertilizer (Ökobilanz 2003 Dtld)[27]



4.3. Upgrading of renewable energy sources

4.3.1. Production of Bio - Oil

Screw presses are used for the cold extraction of oil from rape seeds and sunflower seeds. The oil is squeezed out and the remaining solid material is forced through a die and ejected in the form of pellets or briquettes. The energy requirement represents around 0.8% (estimated by own experience) of the energy content of the raw material. The extracted oil must be left to air in order to release the sulphur content, and then must be filtered.

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27 Ökobilanz 2003 Dtld

Following table shows the yield of oil for different plants[28]. For the energy output by oil a lower heating value of 33 MJ/l is used.

	Energy Input Biomass	Oil yield	Energy Output from Oil	Net Energy Output
Plant	[GJ/ha a]	[l/ha a]	[GJ/ha a]	[GJ/ha a]
Rape	78	1550	52,5	51,1
Sunflower	62	1425	48,9	47

Table 14: Energy output by bio-oil

4.3.2. Controlled crushing / Reduction in particle size

To make the source crop transportable and easy to process it is necessary to crush or reduce the particular size of the material. If possible this should be carried out in the field during the harvesting process. Self-propelled chaff cutting machines cut the crop, lift it and cut it into particulate size down to 5 mm, depending on the purpose of the crop. The energy demand is about 1% (estimated by own experience) from the energy content of the related biomass.

For more extensive upgrading, such as for the production of pellets, a greater reduction of the particle size may be necessary. For wood this can mean a further 0.5% of energy content, and for fibrous material, such as straw, a further 1 to 2%.

4.3.3. Drying of biomass

To render the harvested material suitable for storage and further processing it may be necessary to dry it. To enhance the prospects of good economic return a crop should be harvested when its moisture content is less that 15%. With crops such as Maize and Miscanthus this is possible at temperatures below 0°C. When the crop is meant to the processed at a biogas plant, a dry condition is not necessary. For

28 Bundesamt für Energie BFE, CH-3003 Bern, www.energie-schweiz.ch: etha+ Bioethanol aus Treibstoff incineration, air drying is normally sufficient. With drying it is necessary to differentiate between indirect drying and direct drying. Indirect drying is where the exhaust gases do not come into direct contact with the raw material but the heat is transferred via a heat exchanger. This is suitable for material with low moisture content, such as grain.

Direct drying is where the exhaust gases come into direct contact with the raw material and is appropriate for material with a very high moisture content.

As drying of biomass needs relatively high energy (2,26 MJ/kg at ambient pressure[29]), it will be done when waste heat for drying is already available.

4.3.4. Densification (Production of pellets)

The densification (pelletizing) of plant material has many advantages. The resulting pellets are guaranteed dry, storable and fluid. No bacterial degradation takes place during storage and there is no development of vermin. As a result the processed material is easy to handle and can be easily evaluated on a weight basis (instead of having to be evaluated on a volume basis with extra consideration of moisture content). The bulk density is very high and the handlability good. This enables a high degree of automation at a reasonable price. Due to the homogenity of the pellets the fuel supply to an automatically controlled heating installation, for example, can be more easily measured and regulated. Through the resulting higher efficiency of operation a more favourable energy balance is possible.

The energy requirement of a pelletizing plant is around 1 to 2% (estimated by own experience). The output of a pelletizing press depends directly on the specific weight of the raw material. Wood and straw are relatively difficult to pelletize, where as dried grass and grain are relatively easy. Additives, such as starch and fatty acids, can be used to assist the pelletizing process.

29 IWC Water steam table

4.3.5. Discussion of using biomass

The comparision of different types of biomass shows that earnings of primary energy up to 330 [GJ/ha a] are possible, in future 10 to 15% higher values. The raw biomass may be burned for the production of heat or upgraded to fuel with higher energy density.

Primary energy from biomass may be directly converted to thermal energy for heating purpose with a high efficiency. If the biomass would be burned only for heating purpose, all of the exergy (capability to perform mechanical work) of the biomass would be destroyed. Electrical Energy production by biomass should be considered from the point of heating demand.

Upgrading of biomass is necessary to provide biomass in such a form to be used for transport purposes, using existing infrastructure and substituting conventional fossil fuels.

Upgrading to bio fuel like bio oil show relatively low energy earning up to 50 [GJ/ha a] without using of the by-products. These processes are necessary for substituting conventional fuel, but because of the low energy earnings the by-products should be also used for generating food or energy.

5. Boiler Technology

5.1. Fundamentals / Combustion

5.1.1. Combustion Process

Combustion is the chemical reactions between fuel and oxygen. As combustion is an exothermic reaction, heat is produced at about 800°C to 1200°C due to the heating value of the fuel. Usually the oxygen is taken from the ambient air, which contains about 21 vol% of oxygen. The resulting combustion products are fluegas (CO_2 and H_2O from combustion, N_2 from the air) and ash.

Combustors must ensure a nearly complete combustion by good mixing between biomass (small particles) and air, sufficient high temperature for fasten up chemical reactions and reach ignition temperature of the volatiles, and further more let the combustion some time to complete all the chemical conversions (residence time).

5.1.2. Heat of Combustion

The energy, which will be released during combustion process, is called heating value. The higher heating value (HHV) considers the condensation heat of the steam (H_2O), which will be as combustion product in the flue gas. This condensation heat is not considered in the lower heating value (LHV).

5.1.3. Installation capacity

The suitability of plant material for incineration depends primarily on the scale. In the case of low capacity installations (under 30 kW) only pre-processed material (e.g. pelletized material) is suitable. Medium sized installations (up to around 200 kW), which have sufficient storage space and handling capabilities, can also be fired with chaff. Large installations can be fired with coarse fuels via a hydraulic feed system.

The particle size (grain size) of the fuel material (in mm) should not exceed the boiler output (in kW). This rule of thumb holds up to an output of 500 kW (e.g. a 100 kW boiler installation can accept a fuel particle length up to 100 mm.). In general, the more even the feed rate of the fuel the better the performance and exhaust emission values of the installation. The moisture content of the fuel is also a very significant factor as the vaporisation of the moisture during the combustion process absorbs heat energy. Therefore the moisture content of the fuel should be a low as possible. Plant materials with a high moisture content (over 30%) are only suitable for appropriate designs of boiler installation. It should also be noted that plant material with a low ash melting point requires specially designed firing equipment and ash removal equipment. Furthermore, nitrous oxide emissions (NO and / or NOx, depending on the nitrogen content of the fuel and the furnace temperature) and dust emission (depending on the chemical composition of the plant material) may need to be considered.

The efficiency of high quality incineration plant should be in the region of 90% regardless of the scale of the installation.

For technical reasons, it is strongly recommended to combine such installations with a solar energy installation. To pre-heat the water in the boiler the installation must be run at its lowest setting where exhaust emissions are high and operating efficiency low, thus reducing considerably the life span of the boiler. The operation of district heating plant in summer can result in distribution losses of up to 80%. Individual solar energy installation are much better suited to this scenario.

Another important consideration is the correct sizing of the boiler installation. Small installations, especially in buildings with minimal heating requirements, need to be equipped with buffer storage for periods of low demand.

At large scale installations and distribution networks the plant may never be oversized as this leads to greatly increased investment and operating costs and decreased efficiency. The distribution losses of a district heating plant are between 20 and 30%.

5.1.4. Investment costs

On the following pages the costs for automated installations are described:

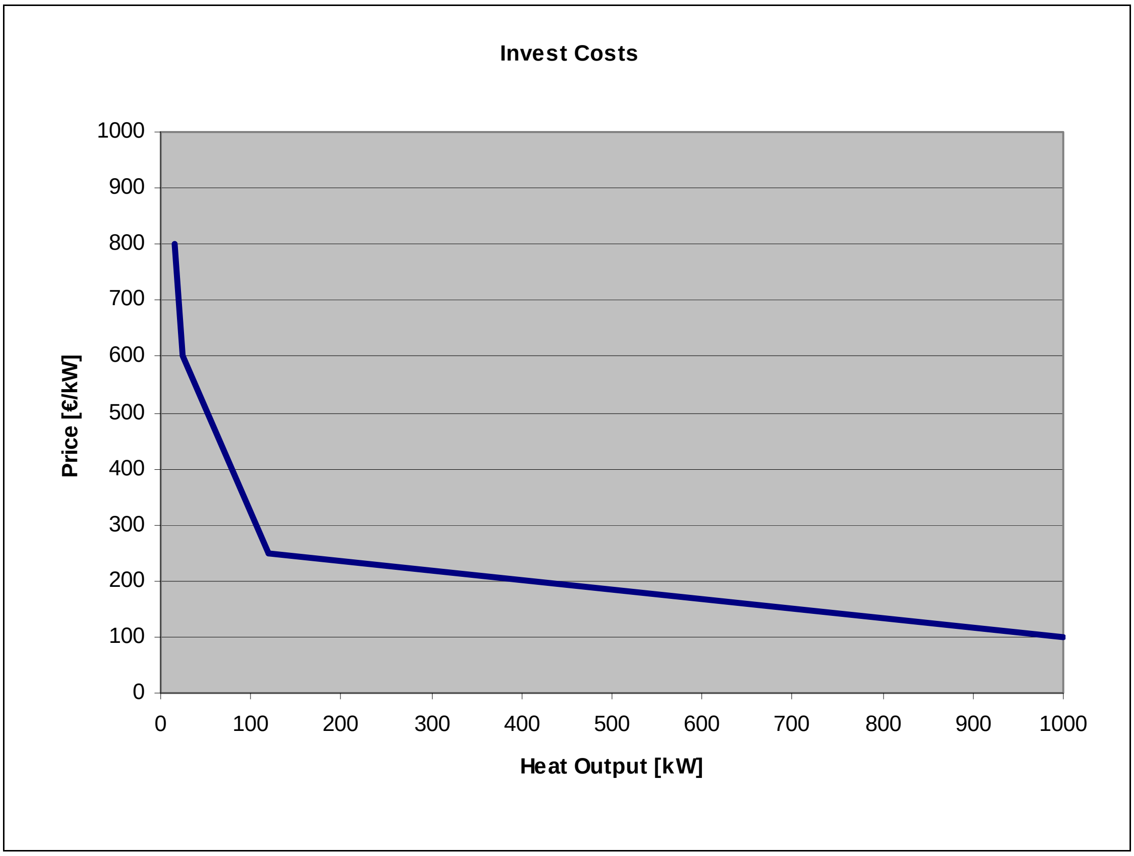

Table 15: Invest cost for incineration

If the boiler system is combined with a solar heating installation, the costs will increase by 15 to 20%.

In the case of district heating installations the incineration plant only represents approx. 1/3 of the total investment cost. The building, distribution system and additional equipment represent 2/3 of the total cost.

5.1.5. Applications / Remarks

For a detached family house an automated pellet fired installation is appropriate due to the low heating capacity required. Such installations are easy to operate, have high reliability, good controllability, low emission levels, and readily available fuel.

For low energy and ultra-low energy houses (passive houses) the inclusion of buffer storage and a solar heating installation is essential. With such houses water heating is generally more of a problem than space heating because therefore a good reserve of warm water is necessary.

For new houses the tile stove represents a good alternative, particularly as a combined source of water and space heating. It is a good provider of radiant heat and has an excellent efficiency rating of over 90%.

For communal systems a high concentration of users per meters of pipe a short overall length of the pipe network are important considerations (kW / m). In addition, the selection of plant and design of installation should be such as to minimise the fuel procurement costs.

5.2. Concept for automatic loaded solid fuel boiler which is suitable to burn different biomass

5.2.1. Aim of development:

The aim of the development is to construct a boiler, which may be used to burn different sorts of biomass, mostly in pressed shape. It should work safe, with reduced emissions, effectively and automatically.

The development should make it possible to make use of plant remains, which could not be used in an optimal way until now.

The market for this development should not be only Western Europe, but also the new EU-members and Eastern Europe.

It is to expect, that the “first class” products (wood pellets) will still be exported from Eastern to Western Europe. For this reason, there should be an alternative provided on the boiler-market, which can also burn the cheaper "second class" products in an effective way.

Also, the EU standards, especially regarding efficiency and emissions should be considered and complied with.

5.2.2. Fuels

Materials of plants in pressed form (pellets) such as corn straw, energy wheat, rape straw, sunflower remains (stems), remains of oil-plants after pressing, miscanthus as well as further biogenic resources and mixtures of these materials.

Free-flowing materials may also be used in unpressed state.

5.2.3. Dimensions

The boilers should be located in a range of performance of approx. 15kW to 50kW, later maybe with more power.

The dimensions have to be designed in a way to fit the boilers in existing boiler rooms. The boiler and the automatic fuel loading system have to be easy to install.

In terms of the costs, the boilers have to be attractive to a larger mass.

5.2.4. Problems

Following problems have to be considered at the development:

1. ash removal
2. melting-point of the ash
3. corrosion resistance
4. feed system
5. low and partial load
6. dust removal (particulate collection)
7. emission characteristics
8. storage room bridging (hang up)

Only when these terms are solved, an adequate success on the market may be expected.

5.2.4.1. Ash removal

Most of the plant materials have a far higher part of ash (up to ten times) as wooden fuels. A reliable ash removal out of the burner is essential for a reliable operation. Furthermore the ash has to be moved from the boiler to an amply dimensioned storage.

Concerning the burners, “slide-in-burners” or maybe burners with a turning grill come into consideration.

5.2.4.2. Melting-point of the ash

The melting-point of the ash of plant materials is mostly far below the one of wood (750°C instead of 1200°C). Due to this reason, precautions have to be taken to prevent the ash from melting and disrupt the combustion.

For example, this is possible with a double-stage combustion or with a purpose-built grill with feed motion.

5.2.4.3. Corrosion resistance

To assure a long lifetime of the boiler, this term is exceedingly important. The corrosion resistance is mainly dependent of the materials the boiler is built of. (For example: cast iron for the burner, high-temperature firebricks for afterburning, no contact between combustion gases and steel parts in certain temperature areas where formic acid and acetic acid are produced, constructive measures etc.)

5.2.4.4. Feed system

It is to mind, that the feed system of the burner, which has to move the fuel reliable into the burner, has to work failure-free. This is primarily achieved by constructive measures.

5.2.4.5. Low- and part load

An optimal operation is also important in low- and part load mode.

A requirement for this is a fast ignition as well as an optimal adjustment between the amount of fuel and air in the different load areas.

5.2.4.6. Dust removal

To meet the thresholds of existing EU-standards, special arrangements for dust removal are required. These start with flue gas guide way and reassurance zones.

An after treatment of the flue gases is essential. Therefore are two approaches:

a) Dust removal with a Micro-E-filter, which may be integrated constructively in the boiler. The flying ash and the combustion ash could be carried into the ash storage
b) Dust removal with a small-washer, which washes the flue gases with a fan rotating in the water. A flue gas temperature below 100°C and a periodic automatic flushing (maintenance free) is required for this technology. This device may be installed separately to the boiler.

5.2.4.7. Emission characteristics

The combustion geometry as well as the air guide way have to be adjusted to the different fuels. This may be achieved through the design and construction of the burner and an optimal afterburning and burn out zone.

Increased CO-emissions can be avoided through this measures.

Regarding the nitrogen-oxide-emissions the ash temperature has to be minded, respectively a too high combustion temperature linked with a flue gas recirculation should be avoided.

5.2.4.8. Storage room bridging

To achieve a safe and failure-free operation, it is to mind that there is no bridging in the storage room, for example caused by a too high part of fuel dust in the fuel storage room. Bridging would cause an interruption of the fuel feed, it can be avoided through a suitable geometry of the storage room and a special mechanism.

5.2.5. Efficiency / Emissions

The basics for efficiency and emissions should be the Euro Norm EN 303 part 5. This is the norm for boilers for biomass with automatic fuel load system with a size up to 300 kW.

5.2.6. Costs for boilers

The market price for a pellet boiler with a power from approximately 15 KW is about 8.000 € in Western Europe. In this price is a margin from approximately 50% for dealers and the plumper included. The net price for Eastern Europe cannot be higher than about 3.000 €. This is the condition, were you can expect to sell a lot of boilers.

6. Implementation and Economy Aspects

6.1. Processing plant

The processing plant consists from 4 main-parts:

The pellet production

The diesel-electrically machine / generator and drying machine

The oil press plant

The operator and owner of this plants should be farmers.

6.1.1. Pellet production

The business includes a pellets production facility with 2.000 tons per year production capacity. This includes machinery with 500 kg per hour capacity and 4.000 hours working time per year. Trough this low capacity the investment costs are not so high and the electrical connection capacity is also relative low.

The initial investments include the complete pellets manufacturing starting from milling, mixing, pellets press, handling, cooling. The electric power is assumed to be supplied by a own generator with a connection capacity of approximate 80 kW.

The performance of this plant should be a mobile construction. So we can reach a high measure from flexibility and have no problems with the authorization. A further effect of the mobile system is good security for investors or financing partners.

6.1.2. Diesel electrically and drying machine

The electrical energy will be generated by a diesel-engine with own produced oil of rape or sunflowers. The electrical capacity of the generator is approximate 100 KW. The waste heat is used for drying the raw material on a drying conveyor belt.

This system is also a mobile construction.

6.1.3. Oil press plant

The oil press plant consists of more oil presses with low capacity, the storage for the seed for rape or sunflower, the filter for the oil, the tanks for oil and the storage for the press cake. The electrical connection capacity is approximate 8 KW.

The plant has a capacity from 72 kg per hour for the seed and a 4.000 hours working time per year. So the machine need 288 tons from seed and produces approximately 100 tons of oil. The waste can be mixed to the pellets. The quantity of the land area for this capacity are approximate 250 ha.

This system is also a mobile construction.

6.2. Boiler manufacturing

6.2.1. Manufacturing

The manufacturer of the heating boilers should be a local company with a high experience in adaptation from steel, welding and building from boilers.

A cooperation with experts from biomass boiler technology is essential.

6.2.2. Installation and service

The plumbers and chimney sweepers get to have a perfect knowledge of biomass burners and boilers. Therefore they have to be well trained. This is an essential condition for installation and service.

For the installation the plumber must have a contract and authorization of the pellet producer. The service and cleaning of the boilers may be done by the plumbers and chimney sweepers.

6.3. Contracting and financing

The consumer gets a contract of the pellet producer or a separate financing company. The contract includes the costs for the boiler, the installation and a certain amount of pellets. The contract includes, that the consumer has to purchase a certain amount of pellets per year. The duration of the contract is limited, for example for 10 years. After this period and a finishing payment the consumer will be the owner of the boiler system.

Benefits for consumers:

No equity capital for the a new heating system

No risk with a new, not familiar, technology

High security regarding supply and service

Lower costs in comparison to gas for heating energy

6.4. Costs for raw material

The main raw material are waste products from crops. That is straw or the seed without oil and the remains of sunflowers. The calculated costs include the costs from harvesting and a profit for the farmer. For the fast growing plants and miscanthus in comparison to other crops (such as wheat, rape) it is calculated, that the local farmer should earn as much money as he did when he planted other crops. For the oil from the sunflowers or rape a market price is also calculated. You can see the expenditures for the different crops can you see in chapter 4.

Calculating a quantity of 4.000 tons of pellets of specific materials following areas are required:

800 ha for straw pellets

400 ha for fast growing plants pellets

200 ha for miscanthus pellets

180 ha for sunflowers pellets

The amount of produced bio oil needed for running the diesel electrically machine / generator requires on area of 180 ha. This area is included in the 180 ha of sunflowers mentioned above.

Furthermore it is important, that the crops must be changed every year on the fields. Sunflower and rape can be planted only every fourth year. Miscanthus has got a lifetime of 20 years and more on one area.

6.5. Analyses of calculation on an example

Calculation of Boiler systems

Boilersystems	**Price/System**	**Sum 500 Systems**	**Calculated Time / year**	**Cost € / t**
Boiler	3.000	1.500.000	10	60
Installation	500	250.000	10	10
Planning/Service	500	250.000	10	10
Sum	**4.000**	**2.000.000**	**10**	**80**

One boiler system costs 4.000 €. These costs the producer of pellets and boilers (or an investor or a financing institute) has to pay. For an estimated period of 10 years and an amount of 5 tons/year of pellets, there is following equation:

$$\frac{4000€}{5t/y*10y}=80€/t$$

It is estimated, that the capacity of the fuel processing plant can be used in an optimal way with 500 boiler systems.

Fuel processing plant

Plant	**Price €**	**Capacity t / year**	**Cost € /t / 10 years**
Pelletplant	150.000	2.000	7,5
Oil Productionplant	30.000	288	1,5
Diesel-Electrically	50.000		2,5
Drier	30.000		1,5
Sum	**230.000**		**13**

The fuel processing plant consists initial costs of 260.000 €. It has a capacity of 2.000 tons / year pellets, that equals costs of 13 € / ton pellets.

$$\frac{260000}{2000t/y*10y}=13€/t$$

Costs of employees

Employees	**Number of Employees**	**Costs € /Year**	**Costs / t**
Worker Producton	2	12.000	6
Worker Manipul.	2	12.000	6
Administration	1	6.000	3
Sum	**5**	**30.000**	**15**

Costs of raw material

Raw Material	**Quantity t/ha**	**Gain € / ha**	**Costs € / t**
Straw	5	250	50
Sunflower		750	
Oil	1	450	450
Cake	2	100	50
Rest fast grow.pl.	20	200	10
Fast growing plant	10	750	38
Miscanthus	20	1.500	38
Average Value			**47**

A minimum average gain of 750 € / ha is estimated. Divided by the different quantities in tons / ha this equals 47 € / t.

The total costs including boiler system, plants, employees and raw materials, this are 155 € / t.

Overview	**Costs / t**
Boilersystems	80
Plants	13
Employees	15
Raw Material	47
Total Costs / t	**155**

Table 16 Investment cost

Source: Mr. Kasmanhuber, Fa. Teccon, by word of mouth, own estimations and experiences

7. Conclusion

The proportionate from biomass on the renewable energies is the highest.

Furthermore agricultural biomass is a considerable proportionate of biomass, but the main part is not used.

Wood will be exported in form of wood pellets in a market which will never be saturated in West Europe.

For the adequate usage of agricultural biomass a further processing essential.

For low operating costs can oil from rape or sunflowers be used. The remains of the plant can be processed by mixing it with other biomass and then processing it to pellets.

A processing plant for production of pellets should have a capacity of about 2.000 tons. With that capacity it can supply 500 boilers in residential.

The area of land that will be needed is about 200 to 800 hectares.

200 to 400 hectare for fast growing plants or miscanthus and 800 hectare for The useage of plant remains.

The complete costs are approximately 155 € per ton. This price includes the investment of the boiler, the installation and service, the investment of the processing plant for the biomass, running costs of the operation and the raw material and is 20% lower in comparison to the market price from wood pellets.

The development and adaptation from the boiler technology for usage of the agricultural biomass is an important factor and a risk what cannot calculated at this time.

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