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Critical review on the pelletizing technology, combustion technology and industrial-scale systems

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INTELLIGENT ENERGY EUROPE

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1 INTRODUCTION

Currently, wood is the predominant fuel used for biomass combustion in Europe. However, caused by the growing demand for material and energy related use wood is getting scarcer nowadays. Consequently, unexplored solid biomass raw materials such as agricultural residues are experiencing growing interest as alternative fuel source. In most European countries preliminary activities in industrial as well as in public sectors have been started to integrate these alternative solid biofuels. However, the market integration of alternative biomass pellets is still hindered by various constraints. To overcome these constraints and strengthen the drivers promising concepts with regard to problems and country specific solutions have to be identified to enhance the relevance of alternative pellets in Europe. There are significant differences for the types of the available raw materials and the local frameworks in the European countries and even between the regions of one country. Thus, the local situations in seven European countries were analysed. This report gives an overview about the available production and combustion technologies. To ensure a transferability of the results of each region, the current situation concerning technical possibilities in production and utilisation of alternative pellets in the European partner countries were monitored and summarised. This includes raw material basis, basic and economic conditions and available pelletising and combustion technologies which were investigated by literature and market surveys as well as interviews with key actors.

2 METHOD AND APPROACH

The report is manly obtained from a comprehensive literature survey as well as results from the MixBioPells project, evaluation of databases and specific input from the MixBioPells project partners. Furthermore, the data was collected with the help of questionnaires, expert interviews and the results of ongoing and previous projects. The report was written in co-operation of VTT and DBFZ with the support of all MixBioPells project partners.

3 KNOWLEDGE BASE

3.1 Literature survey

Each project partner gathered information on on-going and previous projects concerning the topic. The content of the identified projects was discussed by VTT and the project partners in a bilateral way. The international, national and regional on-going and previous projects mainly provide information about the production and utilisation of woody raw materials.

- The “Pellets for Europe”-project aimed to stimulate the European pellet market. The project focused on the following activities: the stimulation of new wood pellet markets, the stimulation of new markets for pellets from agricultural residues, the integration and

development of the European pellet market. The project was co-funded by the EC Altener programme and ended in May 2005. Project activities were further developed in the framework of the project PELLETS@LAS supported by the Intelligent Energy Europe programme. A report on the utilisation of alternative pellets was published /1/.

- The general aim of the IEE Pellets@las project is to promote the development of a transparent and stable European pellet market. Therefore, the main action of the Pellets@las is the collection and provision of pellet market data such as prices and production volumes. In order to provide background information to raw material data, several analytical reports were produced, including country reports, analyses of international pellet trade developments and updates on recent relevant developments such as the ongoing European standardisation of solid biomass. The project ended in December 2009. A study of mixed pellets markets was published within the project /2/. The report includes maps and figures for the production and use of mixed biomass pellets.
- The IEE project "European Pellet Quality Certification" (PELLCERT) has just started. The key objective of the Pellcert project is to create and implement an ambitious and uniform certification system for pellets in Europe, called "ENplus", which will be used both by the heat and the power markets, for European trade but also for imports. In addition, sustainability criteria will be designed to be part of ENplus or come on top and create an "ENplus GREEN" scheme. The project is proposed by a unique consortium of 10 pellets associations (covering AT, BE, DE, ES, FI, FR, HU, IT, SE), ensuring a direct relationship with pellets market players.
- The IEE founded project EUBIONET III is the continuation of the EUBIONET II project (2005 – 2007) and ended in 2011. The EUBIONET III project aimed to increase the use of biomass based fuels in the EU by finding ways to overcome market barriers. National biomass programmes and biomass fuel potentials were analysed especially for different industrial residues and agrobiomass. International trade of biomass fuel was promoted, price mechanisms were analysed and new CN codes for biomass fuels were being proposed. Certification and sustainability criteria for biomass fuels were set in co-operation with market actors. Implementing of new CEN standards for solid biofuels was enhanced. Bioenergy use was promoted by raising awareness on biomass heating aiming at fuel switch to biomass. The appropriate use of biomass resources was assessed by analysing raw material availability within and between bioenergy, forest industry and agricultural sectors.
- Agriforenergy I and II had the objective to promote the use of biomass from agricultural and forestry sector for heating, electricity and transport purpose and to mobilise the large biomass potential from fragmented privately owned forests and from agricultural land by increasing the cooperation among farmers and forest owners.
- Several reports of the IEA Task 32 "Biomass Combustion and Co-Firing" and 40 "Sustainable Bioenergy Trade" were surveyed and the results were included in this report.
- Within the EU-project "BioagroEnergy" pellets production and use of alternative raw materials was demonstrated in the period 2006-2009.

- An Interreg IIIA project “Biomischpellets – Ergebnisse des Forschungsprojektes NEBrA”was done as cooperation between Germany and Poland in 2008. Several mixed biomass pellets were produced and tested in small scale boilers.
- Within the ERA NET Bioenergy project “Development of test methods for non-wood small-scale combustion plants” a study of the driving forces and barriers for the use of non-wood fuels was done in order to evaluate and choose the most promising fuels for small-scale boilers. Furthermore, information on regulations of the authorities in the participating countries relevant for the project as well as other related European documents were gathered. An overview and further compilation of the current state of technology for small scale non wood fuels appliances in Europe, with focus on the participating countries, was done. Measurement equipment and methods were analysed and evaluated experimentally at three test stands. The validation was done by applying statistical methods on the experimentally derived results. The overall results are the basis for a proposal (best practice guideline) for a Europe-wide standard for testing non-wood fuels in small-scale boilers. Finally, a round robin test was planned and the further R&D required for the development of uniform and comparable tests methods were identified.
- The aim of the ERA NET Bioenergy project “Combustion tests of new ash rich biomass” was to identify and to develop practical and economical combustion technology for small-scale combustion of new ash rich biomass pellets. In the course of the project an evaluation of present technology regarding CO, NO_x and particle (especially particulate matter) emissions and ash related problems by burning several new ash rich biomass pellets was done. The aim was also the development and optimisation of practical and economical primary and secondary measures for minimization of emissions.
- The main objective of the Green Pellets project (supported by Life+) is to demonstrate that new dedicated energy crops for solid biomass provide an effective, sustainable and eco-friendly bioenergy source for heating and significantly reduce the greenhouse gas emissions. Herbaceous crops dedicated to the production of solid biomass fuels have environmental advantages such as purification capacities or soil erosion prevention. Energy crops development must be carefully managed in order to reach an acceptable balance between food and non-food supply while avoiding any risks for the environment.
- The ongoing FP7 project “Safepellets” aims to answer the question, where and under which conditions off-gassing and self-heating from biomass pellets occurs and what measures can be undertaken to reduce these risks. In turn, this project will end out into a draft for setting an international standard on safety measures and inspection methods along the whole pellets supply chain (e.g. by developing Material Safety Data Sheets for wood pellets). This safety issue is decisive for the further extension of pellets markets and thereby reflects high relevance for all enterprises in the pellet utilisation chain.
- The ongoing FP7 project “SECTOR” is focussed on the further development of torrefaction-based technologies for the production of solid bioenergy carriers up to pilot-plant scale and beyond and on supporting market introduction of torrefaction-based bioenergy carriers as a commodity renewable solid fuel. The main objective of the project is the further development

of torrefaction and densification technologies for a broad biomass feedstock range including clean woody biomass, forestry residues, agro-residues and imported biomass. Production recipes will be optimised on the basis of extensive logistics and end-use testing. Much attention will be given to the development, quality assurance and standardisation of dedicated analysis and test methods. The experimental work will be accompanied by extensive desk studies to define major biomass-to-end-use value chains, design deployment strategies and scenarios, and conduct a full sustainability assessment. The results will be fed into CEN/ISO working groups and international sustainability forums.

- The objectives of the ongoing FP7 project "AshMelT" is to develop a test method for the assessment of the ash melting characteristics of solid biofuels, the specification of ash melting classes for solid biofuels and to work out a proposal for a European standard for the developed test method

There are also a lot of national projects dealing with the production and combustion which had been idendified by the project partners. However, the topic pelletizing and combustion of alternative and mixed biomass is only covered in very few national projects. Many of these projects were carried out in Germany, Denmark and the Scandinavian coutries; see annex A for further selected national projects. A recent German project called "Biobrennstoffdesign" was finalised in 2011. Several production and combustion tests with mixtures of wood, straw and Miscanthus were conducted in a laboratory-scale fluidized bed unit of the University of Siegen and in small scale combustion appliances by DBFZ.

The projects Pellet@las, Green Pellets, ERA NET Bioenergy project "Combustion tests of new ash rich biomass" and "Development of test methods for non-wood small-scale combustion plants" provided important groundwork since the tasks of these projects were focused on the production and combustion of alternative and to some extent to mixed biomass pellets. Also a literature review was conducted by each project partner in order to identify the important aspects of production and processing of the raw material. The project partners were responsible to sum up the results of the ongoing and previous projects as well as the results of the literature review.

3.2 Results from the interviews

Within the project several key actors along the process chain of alternative mixed biomass pellet production and utilisation were interviewed. The interviews were performed to gather information directly from the experts concerning the topics raw material issues, available and implemented pelletising and combustion technologies and social acceptance of alternative and mixed biomass pellet production and utilisation. Several sets of questionnaires were developed. The first one covered the beginning of the supply chain: raw material issues. In the second set of questionnaires technological aspects of pelletising and combustion were covered. The questionnaires were developed for different groups of stakeholders. Both, quantitative and qualitative questions were included in a balanced way. Afterwards, the key actors from the different defined groups were interviewed by the project partners according to the questionnaire.

3.2.1 Raw material

The interviews on raw material issues have been conducted to gather information on the regional availability of alternative raw materials, existing competitions for raw material, the expected future potential of several biomass resources and actual trading activities. According to the interviews the following raw materials are available for combustion (Figure 1).

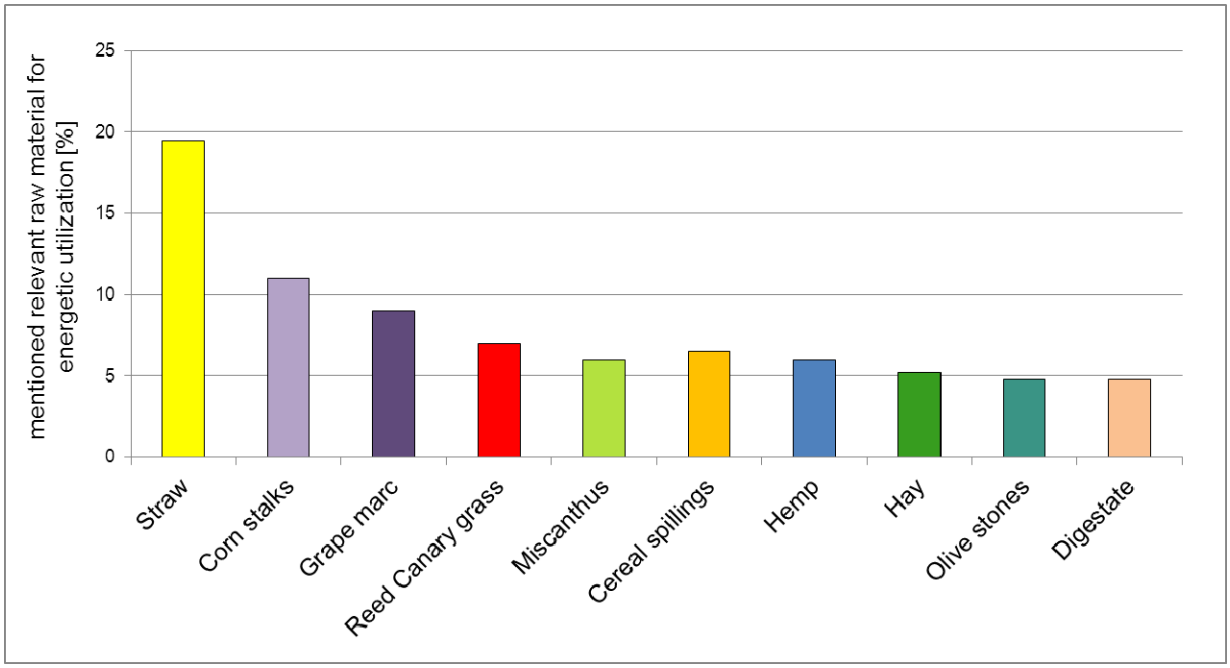


Figure 1: Raw materials, which are considered to be most relevant for the energetic utilization by the interviewed actors in the partner countries (n=38, multiple answers were possible) /3/

In the following the main results of each partner country are summarised.

Austria (AT)

The Austrian interview partners considered Miscanthus, straw hay, grape marc and mash from breweries to be relevant for combustion purpose. For the latter two competitive use is seen.

Germany (DE)

The German interview partners consider Miscanthus, straw, hay, grape marc and digestate to be relevant for combustion.

Finland (FI)

For the Finnish interviewed key actors only reed canary grass and straw appeared relevant for energy-related utilisation. Besides these two raw materials, peat is used as fuel.

Italy (IT)

The Italian interview partners consider Miscanthus, corn residues, straw, hay, grape marc, cereals, vine pruning and poplar from short rotation coppices to be relevant for combustion.

Denmark (DK)

The Danish interview partners consider straw, grain screenings and residues from processing of agricultural commodities such as coffee, shea waste, mash from breweries and potato waste to be relevant for combustion.

Sweden (SE)

The Swedish interview partners Miscanthus, reed canary grass (RCG), peat and hemp to be most relevant for combustion.

Spain (ES)

The Spanish interview partners consider Miscanthus, straw, almond shells and residues from the processing of olives and grapes as relevant for combustion.

Apparently, there are different raw materials available in the different regions of Europe. There is a consensus about the high potential of straw in all partner countries. However, there are also raw materials that are only available in certain regions:

- Reed canary grass in Finland and Sweden
- Grape marc and vine pruning in Austria, Germany, Italy and Spain
- Residues from olive cultivation and processing in Italy and Spain

Both the recent utilisation and future prospects are seen quite differently within the partner countries indicating a differing perception on the availability of biomass and the tendency for its extended use Table 1.

Table 1: Availability, current use and future potential of selected raw materials according to the interviews on raw material /3/

	Agricultural residues	**Energy crops**			**Residues from processing olives and grapes**	
	Straw	**Misc.**	**Reed canary grass**	**Paulownia**	**Olive cultivation**	**Wine growing**
Availability[1]	AT, DK, FI, DE, SE, IT	AT, DE, IT, ES	SE, FI	ES	ES	AT, DE, IT, ES
Current use[2]	AT, DK, FI, DE, ES, SE	AT, DE	SE, FI	ES	ES	ES, DE
Future high potential	AT, DK, FI, ES, SE	AT, DE, IT	SE	ES, SE	ES	AT, ES
Future medium potential	FI, DE, ES	ES	SE			DE
Future low potential		DE				

[1] Does not indicate the available amount.
[2] Use for pelletising in pelletising companies. Does not indicate the produced amount of pellets.
Misc. - Miscanthus

The availability of unused biomass raw materials or residues is important to allow the initiation of any project along the alternative biomass pellets production and utilisation chain. Main issues are the total amount of available biomass, the costs and the required quality. The following aspects can be summarised:

- There are several different biomasses available for combustion within the partner countries (Figure 1).
- The future potential of energy crops and residues from agriculture are considered to be high, especially for straw.
- Regarding the use of alternative biomass, only few concerns about business competitions exist (competitor to food industry, land use competition).
- Main objections exist on the raw material characteristics.
- There is only very limited European trading of alternative and mixed biomass pellets.

3.2.2 Technology issues

The feedback rate (see /3/) for this set of questionnaires was very low indicating the limited experience with alternative raw materials for pelletising and combustion.

Alternative and mixed biomass pellet production

In all countries, most of the raw materials that were seen as available for the region (see questionnaire on raw material) were as well used for production (Table 2).

Table 2 Available vs. used raw materials for combustion /3/

	Energy crops	Residues from agriculture	Residues from landscape gardening	Residues from the processing of rapes	Residues from the processing of olives and grapes	Residues from processing of citrus fruits	Residues from processing of other agricultural commodities	Others
AT								
DK								
FI								
DE								
IT								
ES								
SE								
	Available raw material for combustion							
	Raw material used for pellet production							

Only the most essential pre-treatment is applied. In most cases the interviewed key actors used solely a grinder. Hammer mills are the most commonly used grinder for the reduction of the particle size. Only in very few cases mixers were used. Less than 50 % of the key actors used binders or additives. Considering the technical aspects about 50 % of the average installed pelletising technologies are ring die presses, see Figure 2. Especially in Denmark, Finland and Italy ring dies are common. Furthermore, 35 % of the installed presses are equipped with flat dies and 15 % with other systems like hydraulic presses. No data could be gathered from Sweden.

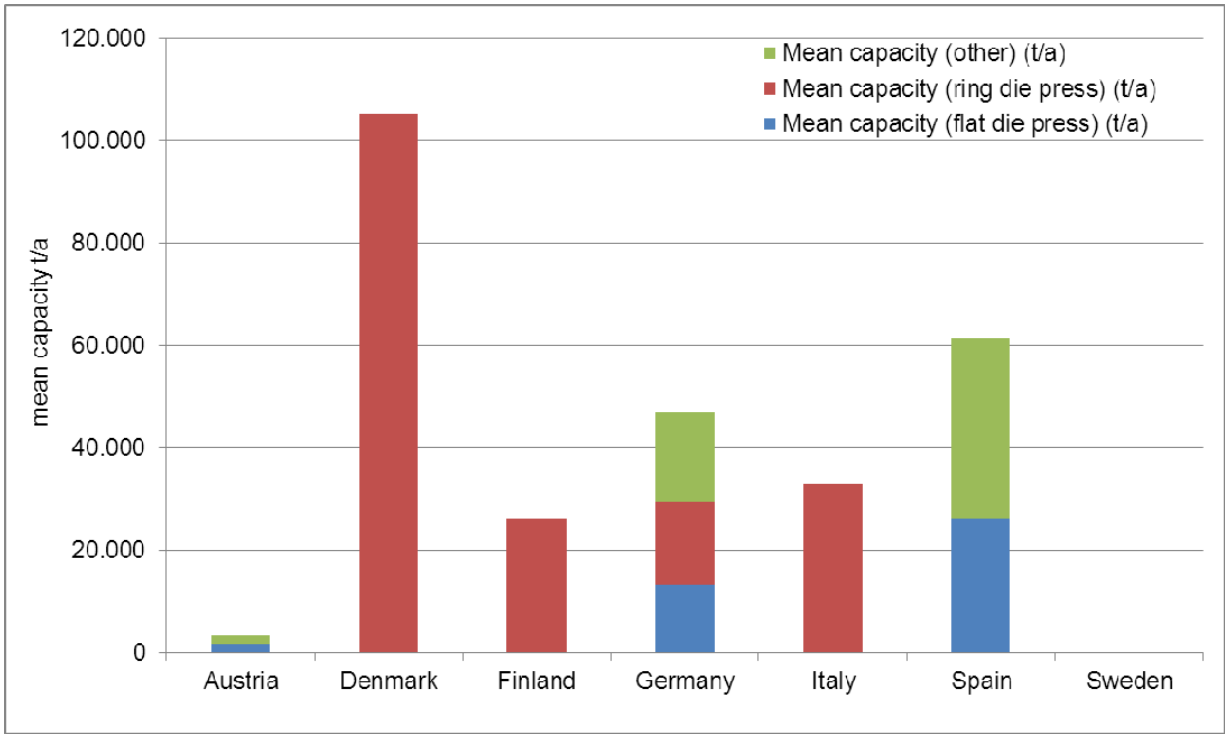


Figure 2: Average distribution of capacities for different press types in different European countries /3/

According to the interviews there is a total press capacity of about 590,000 t/a available within the partner countries (Figure 3). The total real production accumulates to about 373,600 t/a. Thus, capacity utilisation of about 68 % is achieved. In Denmark more than 100,000 t/a straw pellets and in Sweden more than 100,000 t/a straw, peat and reed canary grass pellets are produced. Smaller pellets amounts are produced in Germany with straw, energy crops like Miscanthus and hay, Finland using peat pure and in mixtures with wood and Italy using energy crops, grape marc and agricultural residues. In Austria the production is very low using energy crops and hay. In Austria, Germany, Italy and Sweden there is still a significant share of unused capacity.

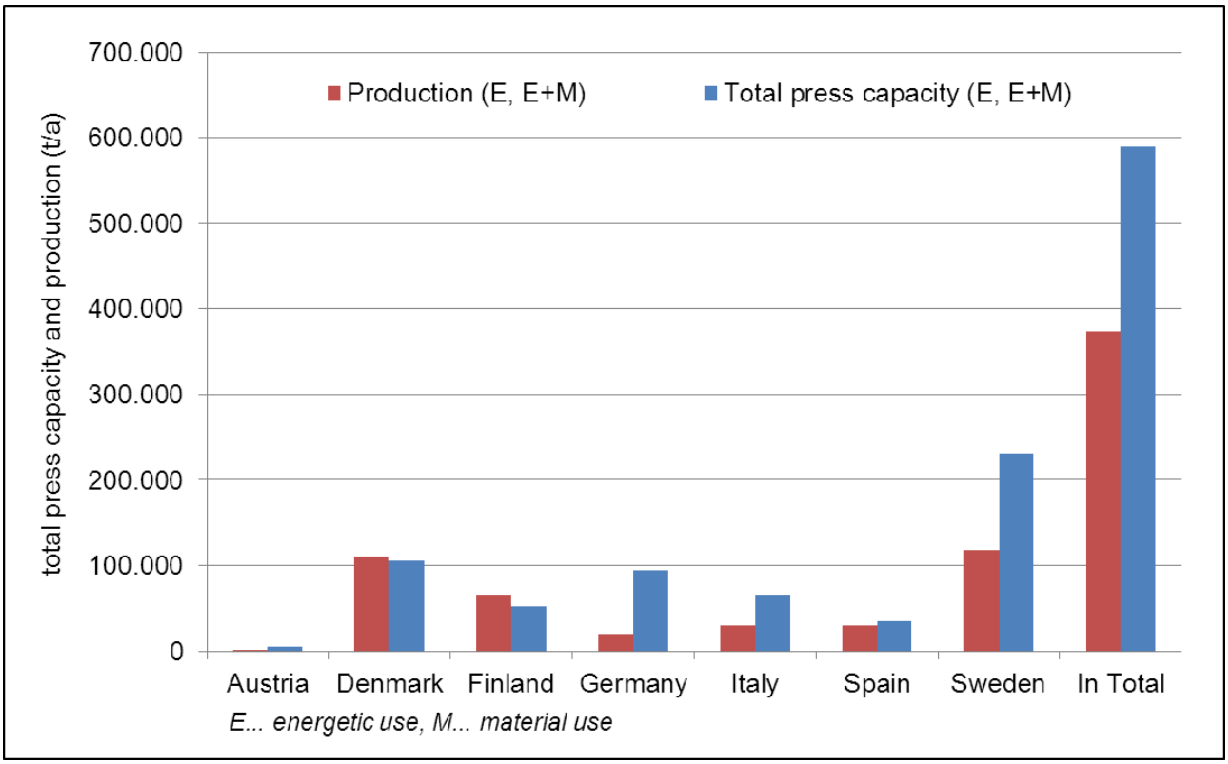


Figure 3: Pellet press capacity vs. pellet production /3/

According to the interviews alternative and mixed biomass pellets are mainly produced from local raw materials and for local use. As main problems in the field of alternative and mixed biomass production the following aspects were identified from the interviews:

- quality of the raw materials,
- difficulties with the pelletising process,
- lack of experience.

Combustion of alternative and mixed biomass pellets

All of the interviewed key actors use alternative and mixed biomass pellets regularly. However, due to the low feedback rate (see /3/) the results given below can only provide an indication. About 30 % of the interviewed key actors have experiences up to 2 years, 25 % up to 5 years and 45 % more than 5 years.

The monitoring of the annual production of boilers was very difficult due to differing available data qualities within the partner countries. Especially in less developed markets public databases are missing. Further details were investigated based on the interviews. Since most of the boiler manufacturers didn't provide their annual sales figures, the results are based on a low feedback rate, Table 3.

Table 3: Number of installed combustion plants according to the interviews /3/

Average thermal input from… (kW)	195
Average thermal input up to… (kW)	59155
Number of installed plants	73

The current use is focused on energy crops and residues from agriculture. According to the interviews only a minority of key actors utilising alternative and mixed biomass pellets is equipped with appropriate combustion systems. Usually boilers for wood pellets, wood chips or wood briquettes are used. This indicates the limited number of appropriated technology available for this purpose or respectively the high price of this technology. Accordingly, several problems resulting from difficult fuel characteristics are not addressed and were reported (Table 4). None of the interviewed key actors had any problems with the combustion.

Table 4: Problems during alternative and mixed biomass combustion /3/

	AT	DK	FI	DE	IT	ES	SE
Dust emission	x		x	x	x		
Corrosion			x		x		x
Slagging and fouling		x	x	x			x
Ash handling	x	x	x	x	x	x	x

Only Danish and German key actors used technical equipment to reduce particulate emissions. According to the interviews, alternative (mixed) biomass is mainly used for heat supply and district heating, i.e. within small and medium scale applications.

Summary and Conclusions

The interviews highlight the limited experience for alternative and mixed biomass pellet production and utilisation that is available at present. The following aspect can be summarised:

- Alternative and mixed biomass pellet production is most important on local and regional level.
- There is still high unused capacity available for alternative mixed biomass pellet production.
- Straw is most commonly used for alternative biomass pellet production.
- Critical fuel parameters and strongly varying fuel characteristic are a major concern.
- There are only very view combustion systems suitable for alternative and mixed biomass pellet combustion available on the market and used. Thus, problems with dust emission, corrosion, ash handling as well as slagging and fouling frequently occur.
- Regional added value and positive effects for sustainability and climate protection are appraised by the interviewed key actors. Consequently, a positive development in the field of energy related utilisation of alternative and mixed biomass pellets is estimated by most of the key actors.

4 RAW MATERIALS AND FUELS

4.1 General

In the following chapter detailed information on available raw materials in certain regions of seven European countries and their characteristic will be given. Possible local raw material suppliers could be any key actors which are dealing with agricultural products and residues. A list of raw material suppliers in the MixBioPells partner countries is included in annex B1. These are e.g. farmers, local farmer cooperatives and companies processing agricultural raw materials (e.g. flour mills, sugar or fruit juice producers). Some of these actors have problems to get rid of their residual materials; some even have to pay for the disposal. Pellet producer will use the raw materials for alternative and mixed biomass pellet production. They could come from the area of wood pellet production, from the pelletizing of alternative materials as litter or fodder or could be new key actors in this field. Due to the more difficult characteristics of alternative raw materials experience with the pelletizing of these materials is of great relevance. Furthermore, the characteristics and the raw material costs have to be figured out. For small and medium scale heating appliances only a few alternative fuels, e.g. straw, are used so far. Most of the alternative fuels are used in dedicated industrial CHP plants or for co-firing in varying fuel proportions.

4.2 Raw material potentials

Within the MixBioPells project the potentials of the three most relevant raw materials have been estimated for each partner country and compared with results from previous studies. The results of the comparison are shown in Figure 4.

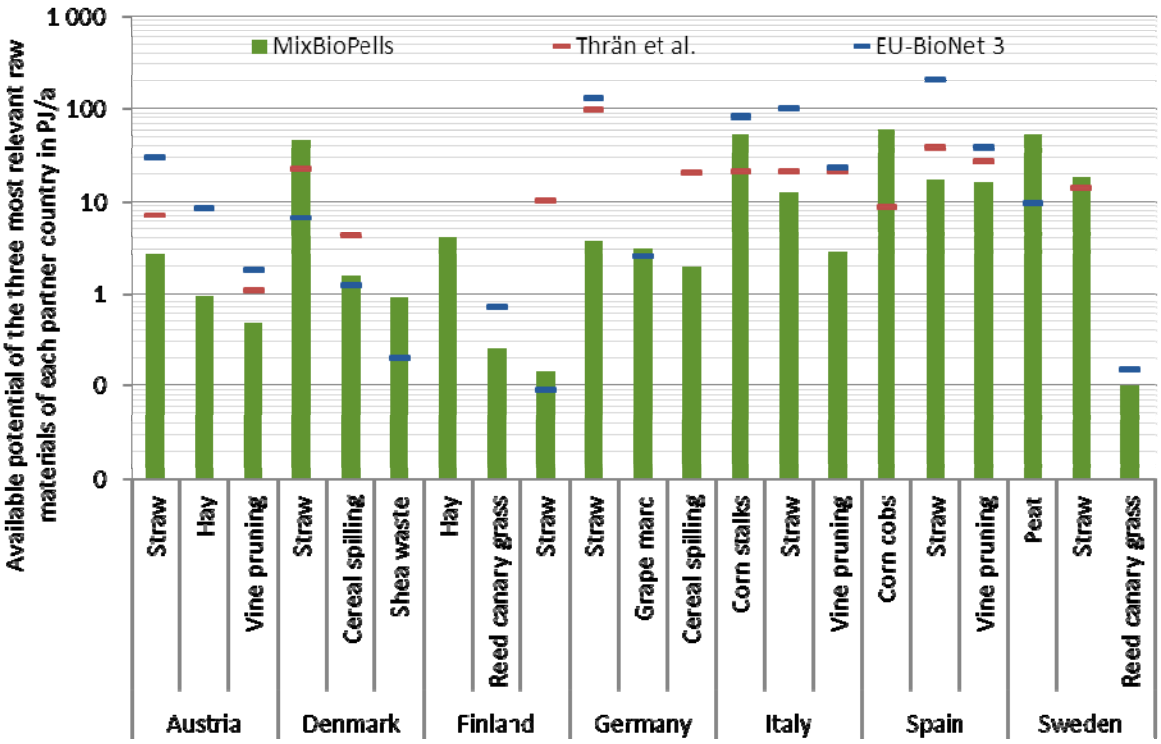


Figure 4: Comparison of the results on available potentials for selected raw materials in seven European countries with results from other studies /4/

4.3 Raw material characteristics

Raw material properties of non-woody biomasses are considerably different from the characteristics of woody biomasses. In general the ash content of non-woody biomass is higher and at the same time ash melting temperatures are found to be lower. High levels of nitrogen, sulphur, potassium and chlorine are often present in alternative biofuels. These elements can form harmful gaseous emissions like NO_x, SO_2, HCl as well as particulate emissions. Moreover, sulphur and chlorine play a major role in corrosion reactions. Table 5, Table 6 and Table 7 give an overview about the raw material properties relevant for the standardisation and for the combustion of selected raw materials. If available, the range of the data is listed, other values are average values. Single values are especially indicated.

Table 5: Combustion-relevant fuel properties

Kind of biomass	Net calorific value	Ash content	Water content	Ash softening temperature	N	S	Cl
	MJ/kg db	% db	%	°C	% db	% db	% db
Miscanthus	17.5-17.9	1.6-3.0	7.5-14.0	820-1172	0.20-0.43	0.02-0.09	0.02-0.13
Reed canary grass	17.5-19.0	4.5-6.0	10.0-15.0	1150-1650	0.30-0.60	0.07-0.08	0.03-0.04
Hemp	19.1-19.6	1.6-2.3	56.6	1200-1250	0.30-1.40	0.06-0.10	0.02-0.30
Straw	17.0-19.0	4.4-7.0	9.0-15.0	800-900	0.30-0.80	0.06-0.12	0.03-0.05
Vine pruning	17.5-18.2	2.2-3.5	15.0	795-1200	0.50-0.75	0.02	0.05-0.07
Corn cobs	16.5	1.0-3.0	6.0-7.0	1100	0.40-0.90	0.03	0.02
Corn stalks	16.6-.17.5	11.0-17.0	15.0-18.0	1250	0.70-0.90	0.08-0.10	n.a.
Cereal spilling	16.5	9.8-10.0	10.0-12.0	1055	1.20-1.70	0.20	0.16-0.3
Hay	18.3	5.5	15.0	820-1150	1.60	0.04	0.09
Rape straw	18.5	3.4	15.0-25.0	n.a.	1.48	0.20	n.a.
Rape press cake	20.8	6.5	9.0	860-1115	5.39	0.36	0.01
Grape marc	18.4-20.8	3.5-11.0	50.0-60.0	1300	1.80-2.20	0.09-0.13	0.02-0.03
Olive residue	17.9-18.3	9.0-12.0	35.0-45.0	1310	2.50	0.15	0.06
Olive stones	16.0-19.0	<1	10.0-12.0	n.a.	<0.01	n.a.	n.a.
Almond shells	17.9-18.6	9.0-12.0	35.0-45.0	1395	0.45-2.50	0.09-0.15	0.02-0.06
Shea waste	18.5[1]	6.0[1]	13.0[1]	n.a.	2.60[1]	0.30[1]	0.10[1]
Carragenan waste	16.6[1]	10.0[1]	80.0[1]	n.a.	0.30[1]	0.70[1]	0.30[1]
Mash from breweries	20.0	4.0	80.0	n.a.	3.30	0.20	0.00
Digestate	15.4	16.5	15.0-20.0	n.a.	2.20	0.60	0.56
Peat	16.5	4.0	10.0-17.0	n.a.	1.20	0.12	0.03

[1] Single value; db…dry basis; n.a….not available

Table 6: Main ash forming elements in mg/kg (dry basis)

Kind of biomass	Al	Ca	Fe	K	Mg	Na	Si	Ti
Miscanthus	79[1]	1600-1790	92-120	3410-7200	300-600	31.5[1]	3930[1]	4-40
Reed canary grass	200-600	900-2000	13849	2300-4330	600-730	200-350	22280-22800	360
Hemp	111	13400	120	15400	2000	130	2100	0
Straw	60-130	2950-3300	120	7120-10000	630-1030	100-120	9000-19300	0
Vine pruning	140-774	4240-10900	390-625	2940-7660	820-840	180-415	4500-5350	64-66
Corn cobs	60[1]	400[1]	70[1]	8500[1]	290[1]	<50[1]	1100[1]	250[1]
Corn stalks	140	7390	680	8190	500	800	14200	70
Cereal spilling	700	2050-5000	500	5380-1340	1170-1400	300	26100	10
Hay	200	5600	60	14000	1740	1000	15000	0
Rape straw	n.a.	n.a.	n.a.	5800[1]	n.a.	170[1]	n.a.	n.a.
Rape press cake	13	3640-6500	0	8890-14100	220-4700	68	750	0
Grape marc	1330	200-6460	1140	7710-18160	60-1100	50-400	720-5260	90
Olive residue	868	7390	670	17000	353-500	46-500	2270-16620	11-80
Olive stones	410-1210	2640-7110	240-800	2550-19340	860	550	6240	90
Almond shells	293[1]	4650[1]	227[1]	7870[1]	687[1]	642[1]	2290[1]	25.7
Shea waste	710[1]	3020[1]	570[1]	38100[1]	3200[1]	100[1]	4630[1]	50000[1]
Carragenan waste	1140[1]	19940[1]	440[1]	4710[1]	4000[1]	1700[1]	5470[1]	110000[1]
Mash from breweries	20-100	4600-5530	440[1]	700-1340	2500-4780	200[1]	830-15990	0
Digestate	1940-5300	5800-28900	200-3600	3540-15000	1140-3000	3000-6550	7200-30600	1970
Peat	8000	4600	n.a.	8000-58000	1200	7000-22000	7900	0

[1] Single value; n.a….not available

Table 7: Heavy metals in mg/kg (dry basis)

Kind of biomass	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Miscanthus	<0.17	0.03-0.09	0.81-6.85	1.4-2.0	<0.03	2.0-3.3	0.16-0.95	1.0-25.5
Reed canary grass	2.10	0.30	3.40	9.1	0.03-0.10	1.0	0.10	11.7[1]
Hemp	0.86	0.11	1.21	4.9	0.03	n.a.	n.a.	2.5
Straw	0.31	0.17	6.56	2.1	0.02	2.2	0.18	1.4
Vine pruning	0.30-0.67	0.05-0.20	0.70-6.80	6.2-28.0	0.10	1.1-1.5	1.90[1]	n.a.
Corn cobs	n.a.	<1[1]	4.00[1]	<4[1]	n.a.	2.0[1]	<1[1]	11.0[1]
Corn stalks	n.a.	0.80	8.00	10.0	0.1	3.3	n.a.	n.a.
Cereal spilling	0.10	0.10	4.60	2.2	0.02	7.0	0.00	1.7
Hay	5.40	0.90	6.40	6.2	0.20	1.2	2.00	6
Rape straw	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rape press cake	0.50	0.40	3.80	4.5	0.03	0.7	0.34	6.4
Grape marc	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Olive residue	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Olive stones	0.09[1]	0.12[1]	7.70[1]	3.9[1]	0[1]	3.7[1].	1.30[1]	5.8[1]
Almond shells	0.20[1]	0.02[1]	7.17[1]	4.5[1]	0.01[1]	3.9[1]	1.18[1]	9.71[1]
Shea waste	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carragenan waste	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mash from breweries	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.06	n.a.
Digestate	<0.70	0.22-1.10	15.00-17.35	38.5	0.05	n.a.	0.04	n.a.
Peat	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[1] Single value; n.a....not available

4.4 Properties of biomass pellets and briquettes

Alternative raw materials have several properties that could be problematic for their handling (Table 8).

Table 8: Properties of alternative raw materials and resulting problems

Property	Problems that might result from the property
higher ash content	• abrasion during the pelletizing process • reduced lifetime of the dies
structural properties (e.g. stalks)	• problems with the feeding system (e.g. blocking)
hardness of the material	• higher energy demand and wear during cutting and milling
different molecular composition	• different compacting properties requiring different dies
varying fuel characteristics and inhomogenous structural features	• handling of these variations requires experience that is rarely available
low energy density	• higher storage and transportation effort

A good possibility to generate a solid biofuel with improved and defined transportation, storage and feeding properties is the agglomeration into pellets or briquettes. Binders can be used to reduce abrasion of dies and to lower the energy consumption during the compacting process. The main advantages of the compacted fuels are summarised in Table 9.

Table 9: Main advantages of the compacted fuels

Quality achieved by pelletizing of the raw materials	Impact
flowability	• fully automated feeding of the combustion system is possible
increased bulk density	• less storage space required • improved transportation quality
reduced fines	• reduced risk of solidification by bridging • lower dust explosion risk during transport and supply
fixed mixture	• prevention of separation in heterogeneous raw material mixtures • improved combustion properties

To utilise biomass as a fuel, the chemical properties and the properties like heating value, water and ash content need to be known. Besides these substance-specific properties the mechanical-physical properties, which can mainly be influenced by the compaction process, are of importance (Table 10). Furthermore, these properties are used to evaluate the quality of a compaction process and of the produced pellets and briquettes.

Table 10: Mechanical and physical properties of compressed fuels with effects to combustion properties

properties	compaction process	influence on combustion system
dimension	regulated by the dimension of the pressing tools	dimensioning of the feeding system of combustion plants
gross density	besides the durability an important measure to evaluate the quality of compacts	with higher particle densities the burnout rate is increasing
bulk density	dependent on the quality of the compaction process	is increasing with increasing gross density; the higher the bulk density the higher the energy density of the biofuel
amount of fines		increasing fines cause problems during the combustion process and lead to higher dust emissions during transport and handling and bridging in the storage system
durability	typically used to evaluate the quality of produced pellets and briquettes (strength, amount of fines)	risk of failures according to blocking and ash melting by fines

Besides these properties of pellets and briquettes the physical properties of the raw material like the particle size distribution and the water content influence the quality of the compacting process. Therewith they influence the quality of the compressed fuels similarly to the compacting process. The quality of alternative biomass briquettes and pellets can also be evaluated based on their physical and mechanical properties, see Table 10 and Table 11.

Table 11: Mechanical and physical properties of different biomass pellets /14/, /15/, /16/

Raw material	Bulk density [kg/m^3]	Gross density [kg/dm^3]	Mechanical durability [Ma.-%]
Wheat straw	479 - 620	1.12 – 1.22	90.6 – 98.5
Rye straw	510 - 640	1.28 – 1.30	94.4 – 98.7
Hay	580	1.17 – 1.21	96.2 – 99.1
Miscanthus	480 - 649	1.11 – 1.33	91.1 – 97.5
Rape press cake	542 - 607	1.11 – 1.13	54.9 – 93.7

As shown in Table 10 and Table 11 the required properties can be kept if the production process is known. According to the raw material, their milling grade and morphological characteristics the compaction process can be difficult. However, the mechanical and physical properties are not

directly depended on the raw material, crucial are the pre-processing of the raw material as well as the process parameters and control of the compaction which are described in the following.

Table 12: Mechanical and physical properties of different biomass briquettes /8/, /17/

Raw material	Dimensions		Bulk density	Gross density	Mechanical durability
	Lenth [mm]	Diameter [mm]	[kg/m^3]	[kg/dm^3]	[Ma.-%]
Bark briquettes	205 - 277	96	-	1.02 – 1.11	-
Wheat straw	-	15 - 25	440 - 493	0.90 – 0.95	95.2 – 99.4
Barley straw	-	15 - 25	318 - 416	0.80 – 0.85	97.5 – 99.0
Hay	-	15 - 25	412 - 438	0.95 – 1.10	90.2 – 95.0
Miscanthus	-	15	-	1.10 – 1.40	99.6

Pellets according to the European product standard EN14961-6 will probably be more expensive due to certification procedures and possibly higher pre-treatment efforts as well as a more demanding pelletizing process to ensure constant quality and fulfilment of the requirements of the standard. The requirements are listed in Table 13. However, these pellets are then applicable for certified combustion appliances that do not require special adaption to the fuel requirements. Thus, overall economics could be still favourable despite the higher fuel costs. In contrast, regional available alternative and mixed biomass pellets could be produced without fulfilling EU-standards. These pellets would be less expensive. However, available combustion technology would have to be adapted to the requirements of the local fuels. This strategy would be particularly suitable on regional level with local contracts for a local fuel. Thus, fuel characteristic would be though critical fairly constant. Thus, the additional costs for adapting the combustion technology could still pay off. Finally, the availability of raw materials for different capacity ranges has been evaluated. This has been realised according to the EN 14961-6. Thus, for small and medium scale utilisation only those raw materials that fulfil the requirements of EN 14961-6: Miscanthus, EN 14961-6: straw and EN 14961-6: reed canary grass well as EN 14961-6: class A should be used (see Table 14). Raw materials that fulfil the requirements of EN 14961-6: class B can be used for medium scale. For industrial scale applications those raw materials with even more critical characteristics should be applied.

Table 13: Requirements of the European product standard EN14961-6 /18/

Parameter	Unit	Straw pellets	Miscanthus pellets	Reed canary grass pellets	class A	class B
					Herbaceous biomass, fruit biomass, blends and mixtures	
Diameter	mm	6 to 25	6 to 25	6 to 25	6 to 25	6 to 25
Length	mm	3.15 ≤ L ≤ 50	3.15 ≤ L ≤ 50	3.15 ≤ L ≤ 50	3,15 ≤ L ≤ 50	3.15 ≤ L ≤ 50
Amount of fines	wt.-%	≤ 1	≤ 1	≤ 1	≤ 2	≤ 3
Mechanical durability	wt.-%	≥ 97.5	≥ 97.5	≥ 96.5	≥ 97.5	≥ 96.0
Bulk density	kg/m³	≥ 600	≥ 580	≥ 550	≥ 600	≥ 600
Moisture content	wt.-%	≤ 10	≤ 10	≤ 12	≤ 12	≤ 15
Ash content (550 °C)	$wt.-\%_{db}$	≤ 6	≤ 4 / ≤ 6	≤ 8 / > 8	≤ 5	≤ 10
Lower heating value	MJ/kg	Minimum value to be stated	Minimum value to be stated	≥ 14.5	≥ 14.1	≥ 13.2
Ash melting temperature	°C	should be stated	should be stated	should be stated	should be stated	should be stated
Additives	-	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
Nitrogen	$wt.-\%_{db}$	≤ 0.7	≤ 0.5	≤ 2.0	≤ 1.5	≤ 2.0
Sulphur	$wt.-\%_{db}$	≤ 0.1	≤ 0.05	≤ 0.2	≤ 0.2	≤ 0.2
Chlorine	$wt.-\%_{db}$	≤ 0.1	≤ 0.08	≤ 0.1	≤ 0.2	≤ 0.2
Arsenic	mg/kg_{db}	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Cadmium	mg/kg_{db}	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5
Chromium	mg/kg_{db}	≤ 50	≤ 50	≤ 50	≤ 50	≤ 50
Copper	mg/kg_{db}	≤ 20	≤ 20	≤ 20	≤ 20	≤ 20
Lead	mg/kg_{db}	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10
Mercury	mg/kg_{db}	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1
Nickel	mg/kg_{db}	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10
Zinc	mg/kg_{db}	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100

d.b. … dry basis

Table 14: Comparison of the fuel characteristics of the most relevant raw materials with the thresholds given in EN14961-6 (A – requirements for ash content according to EN14961-6: Miscanthus A < 4 wt.-% d.b.; Straw A < 6 wt.-% d.b.; RCG A < 8 wt.-% d.b.)

Raw material	EN14961-6: Miscanthus				EN14961-6: Straw				EN14961-6: RCG			
	A	N	S	Cl	A	N	S	Cl	A	N	S	Cl
Miscanthus												
Reed canary grass												
Hemp												
Straw												
Vine pruning												
Corn cobs												
Corn stalks												
Cereal spilling												
Hay												
Rape press cake												
Grape marc												
Olive residue												
Almond shells												
Shea waste												
Carragenan waste												
Mash from breweries												
Digestate												
Peat												

requirements of the EN14961-6 can be fulfilled

requirements of the EN14961-6 can be fulfilled in some cases

requirements of the EN14961-6 can be not fulfilled

d.b. … dry basis

Table 14: (continued) Comparison of the fuel characteristics of the most relevant raw materials with the thresholds given in EN14961-6 (A – requirement for ash content according to EN14961-6: class A - A < 5 wt.-% d.b.; class B - A < 10 wt.-% d.b.)

Raw material	EN14961-6: class A				EN14961-6: class B			
	A	N	S	Cl	A	N	S	Cl
Miscanthus								
Reed canary grass								
Hemp								
Straw								
Vine pruning								
Corn cobs								
Corn stalks								
Cereal spilling								
Hay								
Rape press cake								
Grape marc								
Olive residue								
Almond shells								
Shea waste								
Carragenan waste								
Mash from breweries								
Digestate								
Peat								

requirements of the EN14961-6 can be fulfilled

requirements of the EN14961-6 can be fulfilled in some cases

requirements of the EN14961-6 can be not fulfilled

d.b. … dry basis

5 PELLETISING TECHNOLOGIES

In this chapter specific information on aspects of the pre-treatment and pelletizing technologies will be given. A list of technology suppliers in the MixBioPells partner countries is included in Annex B2.

5.1 State of the art

5.1.1 General

Pressure agglomeration processes like briquetting and pelletising can be used to improve the mechanical and physical properties of solid biofuels. Generally, agglomeration is defined as a process where loose material is compacted to a fuel with different shape and dimension. During the compacting process binding mechanisms result in the formation of larger fuel particle with reduced surface area /5/. Usually, the agglomeration of biomass is used to homogenise the mechanical

properties, increade the density and overall improve the transportation and handling properties. In particular, the following advantages are achieved:

- improvement of the flowability, the dosing and conveying properties of the material,
- increase of the bulk density and thus the improvement of transportation properties,
- removal of the risk of solidification and bridging of fines during transport and storage,
- decrease and removal of dust in the bulk good; thus reduction of dust explosion risks,
- improvement of the recycling properties of by-products, like chipped wood,
- decrease of material loss and prevention of product losses e.g., caused by oxidation and microbiological decomposition,
- stabilisation and homogenisation of heterogeneous mixtures of materials, e.g. for the development of blended pellets,
- improved thermal and combustion properties,
- no change of the chemical properties despite the thermal-mechanical conditioning.

Briquetting is a common process for the improvement of the physical properties of biomass whereby milled and often fine-particle biomass is compressed under high pressure. The occurring friction between the material and the press mould releases heat, which activates the binding forces between the particles. The feasibility of briquetting depends on the plasticity of the biomass. For harder and more brittle material more binding agents are needed to form material bridges between the particles. However, the addition of binding agents is rarely required for biomass briquetting /6/.

The second process for the agglomeration of biomass is pelletising, where grinded biomass is compacted to pellets. Similar to the briquetting process, the material to be pelletised needs to be plastic or deformable and friction between the material and the friction channel leads to heat release responsible for the activation of binding forces. Additionally, the material needs an appropriate moisture content which in the easiest case can be achieved by the addition of water. Pelletising is a well-studied process with established technical equipment arising from the animal feed industry. By the end of the last decade the process was adapted for the production of wood pellets and is of great relevance for the development of alternative biomass pellets. However, alternative raw materials are characterised by different handling properties as well as physical and mechanical characteristics, so that the experiences made with the production of fodder pellets are not directly transferable to alternative biomass fuels /5/, /7/. The agglomeration of fiberous material like wood and herbaceous biomass is mostly based on interlocking bonds. Caused by pressure agglomeration the fibres twist, weave and bend around each other forming a kind of mesh. Additionally, the formation of interlocking bonds is favoured because of the high pore volume.

Accordingly, binders are seldom required for these raw materials. However, binders reduce the abrasion of dies and the energy consumption and are therefore often used. /8/

5.1.2 Survey on pelletising and briquetting processes

Generally, agglomeration processes consist of individual process steps which are similar for briquetting and pelletising, see Figure 5.

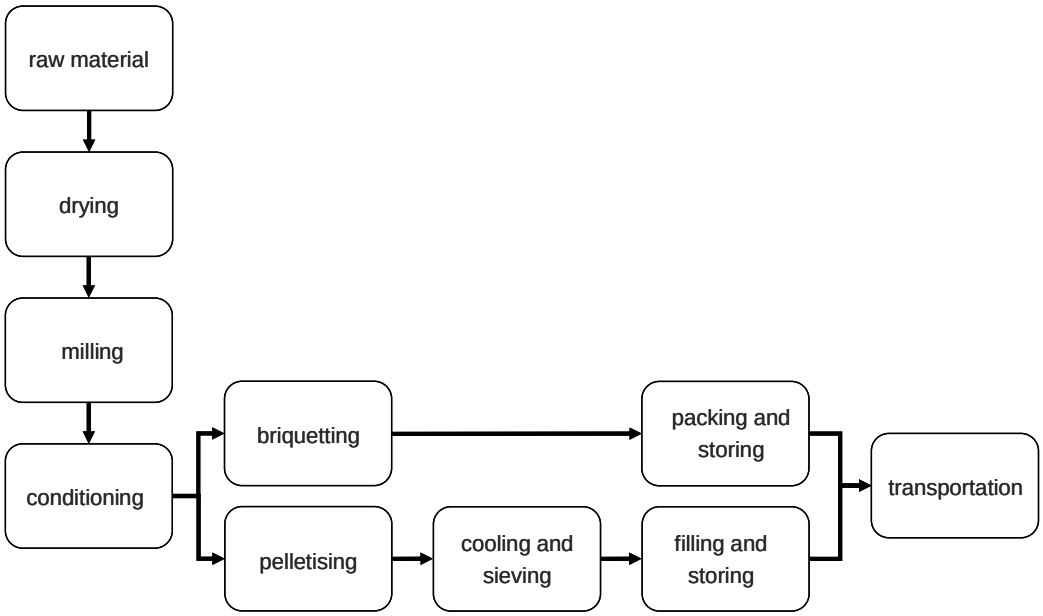


Figure 5: Production process of pellets and briquettes (authors design)

Handling of raw material

Harvesting technology and logistic for straw and hay is well developed. Baling requires no or only minor adaptions (see www.videncenter.dk/gule%20halm%20haefte/Gul_Engelsk/halm-UK04.pdf). Raw materials with high moisture content have to be dried to ensure stable storage conditions. Depending on the raw material specific water content 10 – 15 % is needed to achieve the required physical fuel properties. The bulk density of herbaceous raw materials, e.g. grass and straw, is < 100 kg/m^3 requiring short transport distances.

Drying of raw material

Usually straw and grass are not dried. Some other raw materials need technical drying, which increases the fuel costs. A number of different dryer types may be suited for the purpose, and the final choice should be made after careful consideration of operational and economic factors specific to the application /28/.

In small scale either a batch perforated-floor technology using heated air, or a simple band conveyor using exhaust gas or heated air are dominating. In medium scale, rotary dryer will probably continue to dominate while band dryer can be a possible alternative. In large scale, the use of steam dryers may offer efficiency advantages by recovering low pressure steam or hot water for district heating. In stand-alone applications a low investment is usually emphasised, and correspondingly less energy efficient solutions like flue gas dryers (drum dryers) or band dryers are preferred /28/.

In large scale pellet factories several sophisticated solutions for raw materials drying are used /29/, /30/. Usually, the process is integrated to another process or drying stages are separated to several phases.

Torrefaction

In the recent years several special pre-treatment technologies such as torrefaction were developed and partly available on the market. Torrefied biofuels have been under development since the beginning of this century. Following the pioneering work of ECN and others in the early 2000s in the Netherlands revealing the large techno-economic, environmental and strategic potential, there are now many initiatives worldwide aimed at the marketing of torrefaction technology. Torrefaction is a thermochemical treatment of biomass at 200 to 300 °C. It is carried out under atmospheric conditions and in the absence of oxygen. During the torrefaction process the raw material is heated to remove volatile components and partly degrade macro molecules facilitating the comminution.

Despite claims by several development programs, torrefaction technology is not commercially available yet. The development status of various technology options ranges from pilot-plant to demonstration-scale. The minimum production capacity of the torrefaction plant should be at least 15 000 t /a. Most of the recent work employs woody biomass feedstock /48/. The use of non-woody biomass residues as torrefaction feedstock is limited. Combined torrefaction and densification results in improved (or 2nd generation) pellets or briquettes with superior properties in terms of energy density (up to 50 % higher), water resistance (hydrophobic nature) and grindability.

Milling

Before pelletising, the raw material needs to be grinded which can be realised with different mill types. The type of mill and the milling grade of the raw material has a large influence on the pelletising process, e.g. as raw material wheat, barley and soy extraction goat were used that was grinded by using a hammer mill with a 1 – 4 mm sieve insert and a roller mill with a nip of 0.75 mm /25/. The grinding with a roller mill was found to be unsuitable for pelletising; indeed the energy consumption was lower than for the hammer mill but the mechanical durability of the produced pellets was significantly poorer. Also a higher reduction ratio of the raw material caused a high energy consumption of the grinding process but a negligible higher durability and no energy saving for the pelletising process. Similarly more finely grounded alfalfa resulted in more stable pellets using a hammer mill with 2.0 – 3.2 mm sieves /26/, /31/. In contrast to that pellets produced with diameters of 10 – 25 mm from cut switchgras and straw had better physical-mechanical properties than the pellets produced out of shredded biomass (0 – 4 mm) /32/. The higher strength was attributed to the internal structure of the pellets in which the long strands of the cut material intertwined with each other and were forming additional interlocking bonds /8/. On this basis it can just be concluded that the required reduction grade needs to be tested for the respective biomass. Indeed, with increasing pellet diameter a less fine grinding might be sufficient.

Hammer mills are used most commonly for grinding. For pellet production the straw etc. material in bales should be first debaled and chopped. The length of the chopped stem particles is between 25 to 75 mm. The bigger the press is the coarser the raw material can be. Hammer mill at the end of feeding system grinds the raw material to fine particles. The grinding machine contains a screen, which controls the particle size of the raw material of the pelleting process. In hammer mill the openings are usually 4 – 10 mm. If the raw material is too wet, the openings of the screen are

blocked. Also a higher reduction ratio of the raw material causes a higher energy consumption of the grinding process but a negligible higher or no more durability and no energy saving in the pelleting process.

Mixing and conditioning

The conditioning of the raw material for the pelletising process itself can be done in several ways, by influencing the water content of the raw material, the addition of binders, additives and other raw materials as well as by pre-heating and steam addition.

For all raw materials the optimal water content for the pelletising process is different. It needs to be verified and to be set by conditioning before the compacting. According to the experience of producers the optimal water content for standardised wood pelletising is about 12 Ma.-%. For herbaceous biomass it is slightly higher which is shown by several authors. Experiments with alfalfa showed more stable pellets using a raw material with 14 Ma.-% water content than with 8 Ma.-% /31/, /33/. Similar results have been achieved with reed canary grass where a water content of 14.9 Ma.-% has been optimal for pelletising when testing the interval from 13 to 15.7 Ma.-% /34/. The water content is set before the pelletising process according to the content of the raw material by adding water or steam. When steam is added to the raw material, a second positive effect is achieved - the pre-heating of the material. Exemplarily, the durability of produced blended pellets out of soya meal, ground yellow maize and ground sorghum has been found to be higher and the amount of fines decreased with higher temperatures at the conditioning process /35/. Additionally the energy demand of the pelletising process decreased with higher temperatures but the overall energy demand of the process increased caused by the energy-intensive steam generation. For other raw materials similar results were achieved /26/, /32/, /34/, /36/, /37/.

Besides the described possibilities also the addition of binders, e.g. starchy residues like maize gravel, maize starch and rye flour, can increase the stability of pellets. Experiments have been conducted adding pea meal, lingosulfonate or molasses as binding agents to the pelletising of alfalfa, hay and straw which lead to a higher mechanical durability /23/, /26/, /38/, /39/. Similarly the addition of soy beans and pyrolysis oil showed positive binding effects and was additionally lowering the energy demand of the pellets mill /26/.

Additives such as lime, dolomite, kaolin and talcum powder are added during the pelletising process to improve the combustion properties of biomass by increasing the ash melting temperature of the pellets /40/, /41/. However, the addition of these substances mostly lowers the mechanical durability of the produced pellets which can be counteracted by adding an additional binder /14/, /41/. Besides the above mentioned additives also calcinated dolomite, ophitic, limestone, kaolin and clay can be used /42/, /43/, /44/. For all these additives often increase the ash content of the pellets.

Certain fuel properties, such as the ash content and the concentrations of critical elements, can be set by mixing different raw materials. Furthermore, pelletizing properties may be enhanced by selecting adequate proportions of the respective raw materials. Consequently, the control of the concentrations of N, S and Cl in the raw material mix can be used to limit the formation of harmful emissions formed during combustion. Some emissions correlate well to the content in raw material

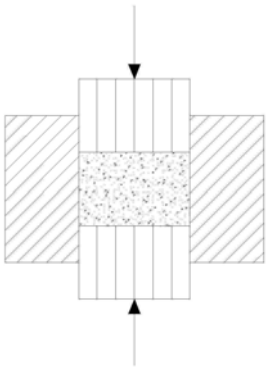
/45/. Mixing of raw materials could be done with two parallel feeding systems. In the systems the rotation speeds, and hence the proportion of the mixes can be controlled easily. At the moment the most common methods are manual mixing on the ground with a bull dozer or by using rotating mechanical mixers.

Compacting

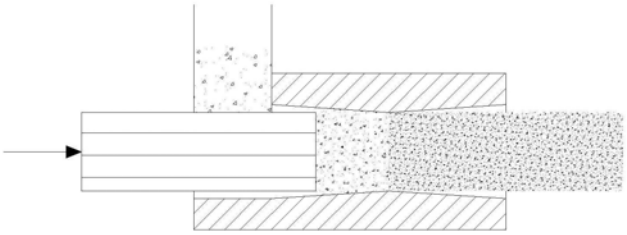
The actual pressure agglomeration takes place by applying external forces to particles in different shaped dies to form enlarged agglomerates. This process can be categorised by the pressure and press mould or the tool configuration. Figure 6 gives an overview of established technologies.

Ram and punch press

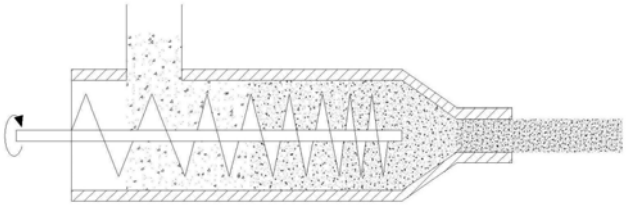
Punch- and-die press



Ram extursion press

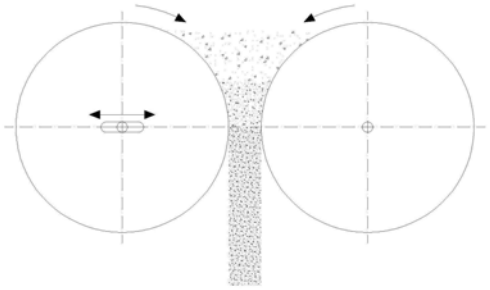


Screw extrusion press



Roller press

Double roller press



Flat die pellet mill with press rollers

Pellet mill with ring die and press rollers

Figure 6: Classification of agglomeration technologies with respect to the employed compacting /5/

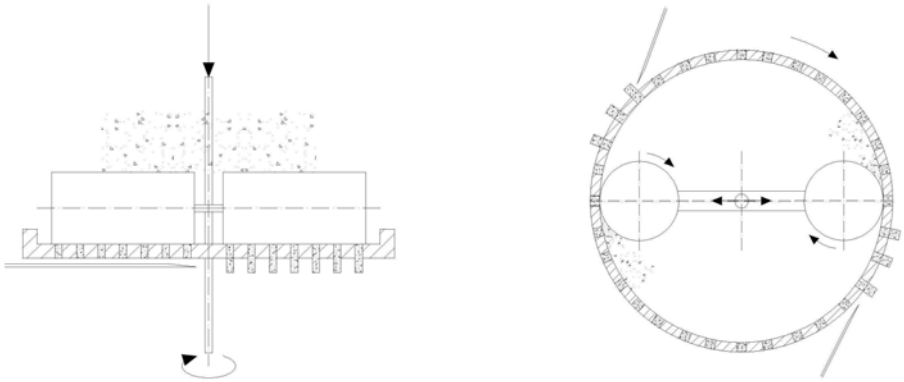


Figure 6: Classification of agglomeration technologies with respect to the employed compacting (continued) /5/

Most of the experiments taken out to determine the influence of the die geometry and of the compression force on the pelletising process have been done with ring dies. The flow rate has a linear relationship with the energy demand of the press /27/. Furthermore, the pelletising process resulted in a higher mechanical durability of the pellets for longer extrusion channels and smaller diameters but also causes a higher energy demand. Above a certain point the pellet press is getting stuck and the material is carbonising in the extrusion channel caused by too much friction and high temperatures. The compaction pressure in pellet mills is another important parameter influencing the pellet quality /26/, /46/, /47/. Several criteria can be used for the quantification of the pellet quality but the mechanical durability is most common.

There are two different pelletizing technologies which are most commonly used for alternative raw materials:

- Pellet mills with flat dies: This technology is common for the production of animal feed pellets.
- Pellet mills with ring dies: This technology is mainly used for the industrial production of wood pellets.

Pellet mills with flat dies are common for the production of animal feed pellets. The roller arrangement consists of at least two rollers which rotate on a stationary die. The feed enters the press from above, falls down by gravity and is diverted evenly to the rollers and the track of the die. Thus, an even material densification between die and rollers and subsequently a uniform extrusion in the die channels occurs. With each rolling sequence the pellet grows by a new layer but altogether the appearance of the pellets is homogeneous. The length of the pellets is adjusted by cutting devices located underneath the die /9/, /10/, /11/. If cylindrical rollers move over the circular track, a continuous travel is only given at one point of the roller surface. The insides edge moves faster and the outside edge slower which causes additional shear force in the material to be pelletised. As a result additional grinding and heating of the material is achieved that might cause uneven material properties and problems when e. g., pelletising pharmaceutical or natural products. Conical press rollers with sloping axes can be used to overcome this effect /5/, /10/.

For the industrial production of wood pellets mainly pellet mills with ring dies are used /17/. Contrary to flat dies mostly the ring die is driven and the material enters the operational area from the open front side of the ring which may cause problems with uneven material distribution across the entire perforated ring area. Thus special feeding devices like paddles or adjustable plows and three rollers are used to overcome this problem. The internal rollers are mostly moved by the continuous flow of feeding material inside the pellet mill. The pelletising principle itself is similar to the pellet mills with flat dies described above where shear forces do not occur since a continuous travel of the rollers on the die is given /10/, /12/, /13/.

5.1.3 Influencing parameters for biomass pellets and briquettes

There has been only limited research done on the briquetting of biomass even though the use of wood briquettes is very common in stoves. The knowledge obtained in the field of coal briquetting can be used as a basis /19/. Concerning the pelletising of biomass, several studies have been performed, often using pellet mills with ring dies. These pellet mills are state of the art for the wood pellet production /17/. Additionally, research has been done in the field of animal food pelletising starting in the seventies. Even though the quality of the produced pellets is different from biofuels, a multitude of these experiments and results is transferable to the compacting of alternative solid biofuels.

For the production of solid biofuels a wide variety of biomass can be used as raw material e.g., energy crops like miscanthus and switchgras but also biomass residues like straw, hay and rape press cake. Several of these materials have been tested for pelletising for the production of biofuels or animal food. The pelletising of pine-needles, switchgras, willow from short rotation coppices and sun flower seed shells were investigated /20/, /21/. Biomasses like wheat straw, hay, Miscanthus and rape press cake have been pelletised for combustion experiments in small scale combustion systems /14/, /22/, /23/, /24/. Furthermore, fodder production with wheat, barley and soy extraction goat /25/ and alfalfa /26/ has been investigated.

Concerning the pelletising process it can be concluded that the mechanical and physical properties of the produced pellets for animal feed are fluctuating and depend strongly on the used raw material. Also the energy demand of the pelletising process depends on the raw material or the raw material mixture /27/. Generally, it is more challenging to produce high quality pellets from herbaceous raw materials.

Different production technologies cannot be compared since only little applications are known and processes are not well documented in detail. Investigations and reports from operators show that apart from the choice of technology the selection of production parameters (particle size, water content, measures of the die, residence time/flow rate) is a crucial issue, and considerable differences are observed depending on the used raw material. The required properties of the European standards can be kept if the production process is known.

5.2 Specific available technologies and solutions in the selected European countries

5.2.1 Special pre-treatment technologies to improve the combustion properties of alternative biomass pellets

Selected selected manufacturers of pre-treatment technologies to improve the fuel properties of alternative biomass pellets are listed in Table 15. The list gives an overview and makes no claim to completeness.

Table 15: Overview about selected manufacturers of pre-treatment technologies to improve the fuel properties of alternative biomass pellets.

Company	Address	Website	pre-treatment technology
Finland			
There are no manufacturers of special pre-treatment technologies.			
Germany			
Florafuel AG	Stahlgruberring 7a D-81829 München	www.florafuel.de	Washing
IFFB	University of Kassel Dept. of Grassland Science and Renewable Plant Resources Nordbahnhofstr. 1a D-37213 Witzenhausen	www.prograss.eu	Pressing
Lehmann Maschinenbau	Jocketa-Bahnhofstraße 34 08543 Pöhl	www.lehmann-maschinenbau.de	Defibring
Denmark			
Andritz	Glentevej 5-7 6705 Esbjerg Ø	www.Andritz.com	Torrefaction
Italy			
There are no manufacturers of special pre-treatment technologies.			
Sweden			
There are no manufacturers of special pre-treatment technologies.			
Spain			
There are no manufacturers of special pre-treatment technologies.			
Austria			
Andritz AG /Polytechnik	ANDRITZ AG Stattegger Strasse 18 8045 Graz, Austria	www.andritz.com	Torrefaction

In the following specific and market relevant technologies are described for each country.

Germany

Major German developments of pre-treatment technologies to improve the fuel properties of alternative biomass pellets were done on washing, hydrothermal carbonisation and defibration techniques.

Defibrication technologies

In the defibration process, the material is constantly exposed to crushing procedures, i.e. tearing, squeezing, milling and transported into a functional area. The raw material is treated with a double screw extruder to improve the binding of the raw material during the pelletising process

Figure 6: Double screw extruder (source: www.lehmann-maschinenbau.de)

Increased number of gear results in elevated pressure and temperature. Since the material has to pass several different chambers, it is exposed to areas of pressure and areas of release. This leads to the plastification of the material, provided the material is suitable for plastification, or to the defibration due to the "wet steam explosion effect" during release at the exit port. The energy input leads to the activation of the surface (interface mechanics). At the same time it allows for the intense mixing/blending of different materials. The plastification or defibration process may be intensified or modified by additional application of heating or cooling. Material type, humidity, material treatment, level of interfering material and output quantity are crucial measures for a high quality and performance.

Table 16: Technical data double screw extruder (source: www.lehmann-maschinenbau.de)

Type	Mode of drive	Output material[1)]	Output performance[2)]	Dimensions L • W • H [m]	Weight [t]
MSZK 15	E-motor 15 kW	wood fibre, DSD-compactate	0.8 – 1.0 m³/h 0.2 – 0.3 t/h	2.15 x 1.00 x 1.28	approx. 0.9
MSZK 65	E-motor or diesel 65 kW	wood fibre DSD-compactate	2.5 – 6.0 m³/h 0.5 – 0.8 t/h	D 3.80 x 0.85 x 1.27 E 4.30 x 0.85 x 1.27	approx. 2.8
MSZK 90	E-motor or diesel 90 kW	wood fibre DSD-compactate	2.6 – 6.8 m³/h 0.6 – 1.0 t/h	D 3.80 x 0.85 x 1.27 E 4,30 x 0.85 x 1.27	approx. 3.0
MSZK 180	E-motor or diesel 180 kW	wood fibre DSD-compactate	9.0 – 17.0 m³/h 1.4 – 2.0 t/h	D 6.00 x 1.20 x 1.80 E 5.00 x 1.20 x 1.80	approx. 10.0
MSZK 250	E-motor or diesel 250 kW	wood fibre DSD-compactate	9.0 – 17.0 m³/h 1.5 – 2.5 t/h	D 6.50 x 1.20 x 1.80 E 5.50 x 1.20 x 1.80	approx. 10.0

1) other materials on request, 2) depending on material and humidity
L= length without additional module; W=width; H=height; D= diesel engine; E= electric motor

Washing and Pressing technologies

The **IFBB technique** aims at the separation of the grassland silage into a solid part for combustion and a liquid fraction for biogas production. The extraction of minerals and easily digestible compounds into the liquid significantly improves the combustion performance of the fuel and renders the press fluid to a valuable substrate for biogas production.

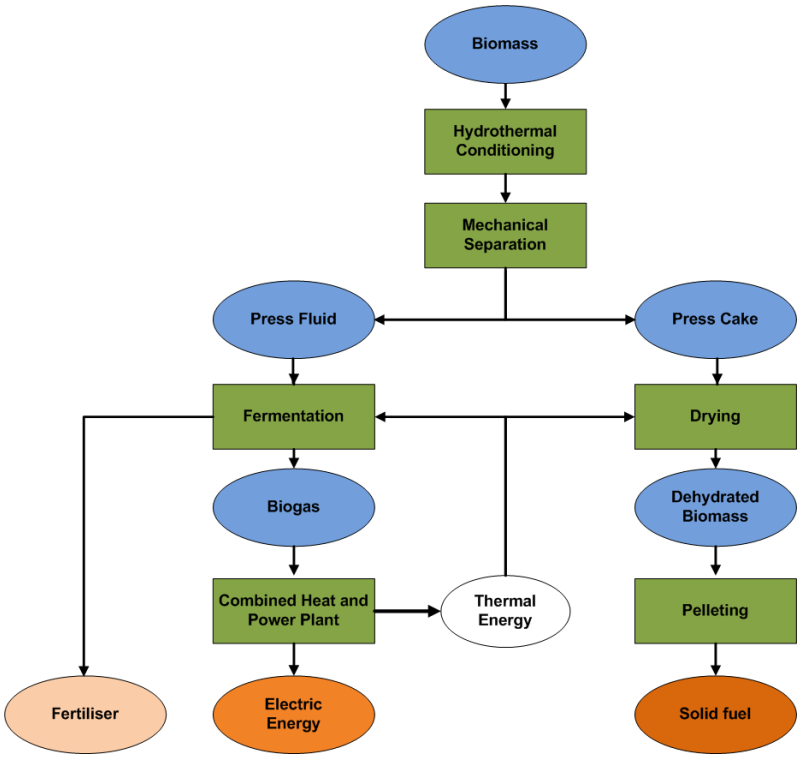


Figure 7: Process flow chart of the IFBB technology /49/

Procedural Design is /49/:

- Silage is first mashed with 40°C warm water,
- Separation of the mashed biomass into a solid, fibrous fraction (press cake) to be used as a solid fuel, and a liquid, biologically convertible fraction (press fluid) for the production of biogas,
- Biogas production from the press fluid and its use in a combined heat and power plant (CHP) to produce electricity and heat,
- Drying of the press cake and supply of a fuel with improved combustion characteristics compared to the untreated biomass,

The unused waste heat from CHP can be used for the year-round drying of the press cake. Digestates can be used as valuable fertiliser containing a lot of nutrients. Using a mobile PROGRASS prototype the IFBB technique is being assessed on pilot scale, and demonstrated in 2010 and 2011 in Vogelsberg, Hessen/Germany, and in the European partner regions of Wales and Estonia. The accompanying scientific research analyses the quality of silage and fuel, the digester dynamics and

the biogas yield as well as the feasibility of the technical concept in a continuously operating mode. Apart from research work and continuous press cake and pellet production, the distribution of the new technical approach is one of the main tasks of the project. Technical data of the demonstration plant /49/:

- Processing capacity: 400 kg silage per day
- Fuel production: 90 kg dry matter per day
- Biogas yield: 7 kW

First results of the IFBB prototype reveal that pre-treatment and mechanical dehydration lead to significantly improved combustion characteristics of the fuel. Dry matter content of the silage can be increased by 20 % resulting in reduced heat demand for the drying process /49/. Mineral matter content of the biomass which is detrimental to combustion process can be reduced by the pressing. In particular, the content of elements responsible for ash softening and corrosion like potassium and chlorine is decreased in the press cake. In contrast, there is only limited reduction of nitrogen and sulphur content. Thus, the ash softening temperature can be increased to about 1200°C and also the lower heating value is elevated to more than 18.5 MJ/kg (dry basis) /49/. Furthermore, the improved combustion properties of the press cake result in decreased requirements regarding flue gas cleaning, e.g dust precipitators and the transport volume of the residues can be reduced by drying and compacting.

A similar process was developed by **Florafuel AG** and the Institute of Water Engineering at the University of the Federal Armed Forces in Munich. The objective was to produce a concept, develop the "florafuel®" plant and to optimise the latter to provide a low pollutant / pollutant-free fuel. The effect of reducing content of problematic elements such as potassium and chlorine was investigated during the development phase. It was shown that a significant reduction of such problematic elements can be realised with this process, see Figure 8 and Figure 9.

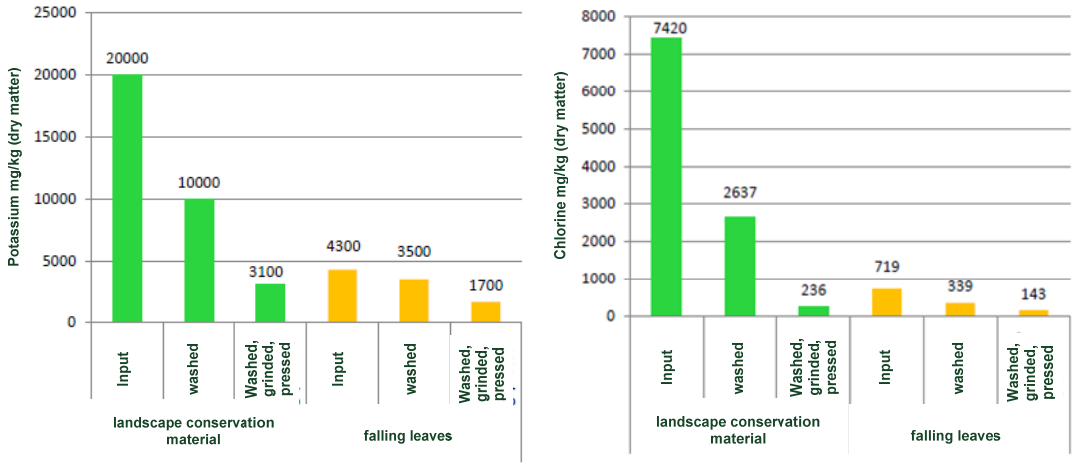


Figure 8: Reduction of potassium and chlorine in the fuel by using the Flora-Fuel technology /50/

Figure 9: Flora-Fuel plant /50/

Potential biomass types to be considered include: grass from agriculture, roadside green belt, reeds, biomass from landscaping and maintenance material, horse manure and fermentation waste from biogas plants. Farmers should be considered as potential operators of the "florafuel®" plants, as they have both the pasture land and the appropriated harvesting technology. In most cases, the required real estate (barns, halls) for the production plant is available at the farmer's premises. Moreover, the growing task of agriculture in the area of rural and nature conservation must be emphasised. The Florafuel process is complementary to the biogasification plants. Furthermore, the process is a alternative for power generation and a chance for farmers to develop additional income opportunities, which are also within their familiar field of activity. The process steps are displayed in Figure 10.

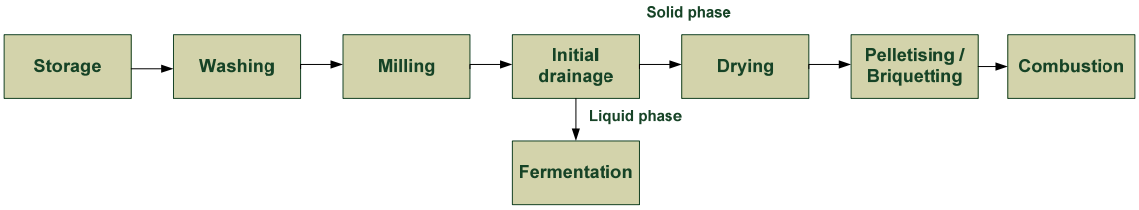


Figure 10: Process flow chart of the Flora Fuel technology /50/ (modified)

In the future the following aspects will be the main challenges /50/:

- Optimisation of the pilot plant
- Further adaptionto allow the production of mixed biomass pellets and the pretreatment of organic waste

Torrefaction technologies

In Germany, there is no technology provider for torrefaction technologies located so far. However, in three on-going projects torrefaction characteristics of non-woody raw materials are investigated, Table 17.

Table 17: Selected on-going German torrefaction projects

Project	Funding programme	Subject
SECTOR: Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction (Project start: 01.01.2012)	FP7-ENERGY	The SECTOR project is focussed on the further development of torrefaction-based technologies for the production of solid bioenergy carriers up to pilot-plant scale and beyond, and on supporting the market introduction of torrefaction-based bioenergy carriers as a commodity renewable solid fuel.
Torrefaction - Qualification of torrefied biogenic residues for use in large-scale power plants (01.09.2010 - 31.08.2013)	Agency for Renewable Resources (FNR)	Within this project, the influence of torrefied biomass in combustion processes will be researched in pilot-scale plants and numerical simulation.
TORBIMA: Torrefaction – a process for homogenisation of problematic biomass raw materials for energetic use (Project start: 01.07.2011)	Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU)	The objective of the collaboration project between DBFZ and Pusch AG is the development of a process for the homogenisation of problematic biomass raw materials for combustion purposes. The processes torrefaction and pelletising will be optimised to improved combustion characteristics oft he raw materials. Thus, the Pusch AG will develop a torrefaction plant which will be combined with an existing pelletising plant of Pusch AG.

Table 18: Selected torrefaction initiatives in Germany

Developer	Reactor technology	Supplier	Production capacity [t/a]	Used raw materials
No initiatives on the German market available				

Austria

Alternative pellets should be as cheap as possible. Thus, only torrefaction as pre-treatment technology for alternative and mixed biomass pellets is of interest in Austria since mainly farmers are interested in the production of alternative and mixed biomass pellets. In other cases the efforts for additional equipment and production will be too high. In Austria, Andritz is developing the ACB process. The torrefaction pilot plant of Andritz AG was built in 2011 in cooperation with Polytechnik in Frohnleiten (Styria). Handling and production volumes have to be analyzed before production starts in 2013. The key data is listed in Table 19 and the process is described in Table 20.

Table 19: Selected torrefaction initiatives in Austria

Developer	Reactor technology	Supplier	Production capacity [t/a]	Used raw materials
Ebes AG	Rotary drum	Andritz	10,000	ligneous biomass

Table 20: Description of the ACB© torrefaction process

Process step	Technology	Description
Drying	BDS Drying Technology	• Closed loop belt dryer, directly heated with fluegas • Utilization of waste heat after reactor • Optimum efficiency (fluegastemperature approx. 60-70°C) • Industrial approved technology • worldwide 22 reference dryer for biomass and sewage sludge
Torrefaction	Andritz Reactor Technology	• Rotating, indirectly heated drum-reactor • Retention time control via special drum internals • Fluegas flow-pattern prevents condensation problems • High flexibility in terms of allowable particle size (no clogging, channeling or increase in pressure-drop) • Andritz sealing technology to prevent oxygen entrance • Construction based on Andritz DDS (Drum Drying systems > 100 lines in operation worldwide)
Energy Supply (lean gas combustion)	Polytechnik Firing Technology	• Hydraulic reciprocating grate firing (1.500 kW) • Burner for hot lean gas (280 °C) • Maximum heat coverage from lean gas • Additional fuel: wood chips 20 – 55% water content • Long residual time for low emissions • Mixing chamber for hot gas generation (400 °C)

Table 21: Description of the ACB© torrefaction process (continued)

Process step	Technology	Description
Preparation for densification	Andritz Cooling, Milling and Conditioning Technology	**Cooling:** • cooling screw technology to efficiently cool torrefied material down to temperatures where torrefaction reactions are stopped and material is safe to handle **Size Reduction:** • Hammermill (Multimill or Optimill) for appropriate size reduction. **Conditioning:** • to activate remaining natural or additional binders by applying: Moisture / Retention Time / Heat • Andritz available conditioning equipment: - Optimum mixing efficiency in CM conditioners - Retention-time controlled operation in CRT conditioners
Densification by Pelletizing	Andritz Pelletizing Technology: Andritz Pellet-Coolers:	No details available Air-cooler design for bulk material cooling.

In Table 21 Austrain torrefaction projects are summarised.

Table 21: Selected ongoing Austrain torrefaction projects

Project	Funding programme	Subject
SECTOR: Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction (Project start: 01.01.2012)	FP7-ENERGY	The SECTOR project is focussed on the further development of torrefaction-based technologies for the production of solid bioenergy carriers up to pilot-plant scale and beyond, and on supporting the market introduction of torrefaction-based bioenergy carriers as a commodity renewable solid fuel.
TorrChance -Analyse und Bewertung der Chancen torrefizierter Biomasse auf dem österreichischen Energiemarkt (Project start March 2012)	Intelligente Produktion FTI Initiative	The project aims to analyze and assess the restraints and drivers for torrefied biomass on the Austrian energy market and the identification of minimum standards for the fuel in terms of logistics, storage and combustion. Thereby the approach of a holistic examination and analysis of the bio refinery concept "torrefied biomass," beginning at the available raw materials to the end users of the torrefied products, is taken. Within this approach the focus concentrates on the investigation on costs along the value chain.

Denmark

In Denmark, the company Andritz is developing torrefaction technologies. However, there is no public information available.

Italy

In Italy pellets or briquettes of pretreated alternative biomass were not produced by using special pre-treatment technologies such as torrefaction, washing or pressing, hydrothermal carbonization and defibrication. Although the use of these technologies become more and more interesting for several key actors, only a few producers of alternative pellets are working on pellet plants designed for different purposes (production of animal feed, wood pellets etc.). It can be assumed that only with the development of the alternative pellet market may be taken into consideration also the most advanced technologies to improve the quality of the raw materials.

Sweden

Special pre-treatment technologies are not of interest for Swedish market at the moment. The market is accustomed to use fuels with „low“ quality, e.g. high moisture content. In Sweden the torrefaction project “Bioendev” develops techniques and methods of energy extraction from biological raw materials including industrial plants for torrefaction of biomass and synthesize "green" fuels and chemicals. Further torrefaction initiatives are listed in Table 22.

Table 22: Selected ongoing Swedish torrefaction projects

Developer	Reactor technology	Supplier	Production capacity [t/a]	Used raw materials
Vattenfall	Moving bed	Unknown	Unknown	Unknown
Bioenergy Development North AB (Bioendev)	Rotary drum	Unknown	25,000 – 30,000	Wood

Spain

In Spain there are few technologies developed, far more they are imported from other European countries. Furthermore, it is not common to do any pre-treatment during the production. In all cases a specific washing technology is not used because the producers try to reduce any activity which might increase the cost of the final product.

Finland

Finland is not any technology provider of the torrefaction or special pre-treatment technology. However, the Finnish industry and research is interested in this topic. The “BioBoost” project about hydrothermal carbonisation has just been started by Neste Oil Oy from Finland focussing on dry and wet residual biomass and wastes as feedstock No initiatives on the market available about defibrication technologies and washing and pressing technologies.

5.2.2 Pelletising technologies for the production of alternative and mixed biomass pellets for combustion purposes

Up to now, there is only limited production of pellets or briquettes from non-woody biomass raw materials or mixtures. Established production chains exist for the production of animal feed or litter. However, there is no large scale industry manufacturing products for combustion purposes. Non-woody fuel pellets and briquettes are mainly produced by committed farmers, farmer cooperatives and some smaller pellets manufacturers. For the production of alternative, new solid biofuels several raw materials like energy crops and residues can be considered. For the compaction of these materials different technologies are available resulting in the production of briquettes or pellets. In the last years, some research has been done in the field of pelletising for animal food production. Subsequently, several synergies can be used for the development of biofuel pellets since the results might be adapted even though higher qualities are required for fuel pellets. In contrast, the research carried out in the field of briquetting is negligible. In annex B3 key actors producing fuel pellets and/or briquettes are listed.

Machine types, ring die or flat die presses, are manufactured up to 8 t/h. The smallest presses produce less than 100 kg/h. At least in the Nordic countries big industrial presses are operating with ring dies. Investigations and reports from operators show that apart from the choice of technology the selection of production parameters (particle size, water content, measures of the die, residence time/flow rate) is a crucial issue, and considerable differences are observed dependent to the raw material used. Different raw materials may require different dies. These costs are high regarding the economic efficiency of the production – especially for small farmers.

- During different project meetings with the stakeholders were underlined the main problems of the mixed pellets, which can be summarized as follows:
- some biomasses (e.g.: paddy straw) may contain large amounts of silica; this impurity leads to an higher abrasion of dies, which can reduce the machinery life up to 30%;

- the reduced amounts of lignin can affect the mechanical work of the pellet mill; moreover, lignin content influence the product durability and energy consumption: a higher lignin content leads to a higher durability product. This problem, for instance, can arise with straw;
- it is difficult to manage the production of mixtures due to the different optimum working settings of the machinery for the different materials;
- the particle-size of the material before the pelletizing operation should be very homogeneous in order to reduce the consumption;
- the ring die seems to be more suitable for the lingo-cellulosic materials, but there are also some controversial aspects between different manufacturers. The advantages of ring die pellet mills should be the reduced roller and wear of the dies. Also energy consumption seems to be lower using ring dies, but the purchase price is generally bigger.

An overview about manufacturers of pelletising and briquetting technologies are included in annex B2.

Flat and ring die presses

For industrial pellet production of wood pellets mainly pellet mills with ring dies are used /22/. Most of the experiences on the production of non woody biomass pellets are based on this technology too. Examples of commercially available ring and flat die presses are displayed in Figure 11.

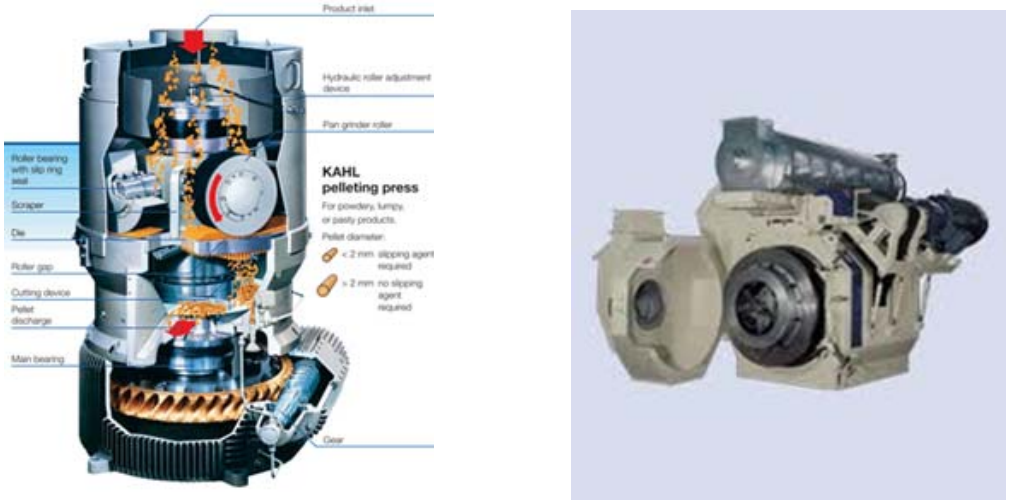


Figure 11: Kahl flat die press (left) and Münch ring die press (right), (source: www.amandus-kahl-group.de, www.muench-gmbh.com)

Most of the manufacturers of pelletising and briquetting machines are located in Germany and Italy. The technical data of selected flat and ring die machines are summarised in Table 23.

Table 23: Technical data of selected flat and ring die presses

Company	Press	Type of drive	Type of die	Drive power [kW]	Production capacity [t/h]	Inside diameter of die [mm]	Amount of rollers
Münch-Edelstahl	RMP 350	V-belt	ring	2 x 30	~ 0.9	320	2
	RMP 420			2 x 50	~ 1.7	420	
	RMP 520			2 x 75	~ 2.0	520	
	RMP 660			2 x 110	~ 2.9	660	
	RMP 800			2 x 132	~ 4.2	800	
Amandus Kahl	33-390	V-belt	flat	30	0.3	230	2
	38-600			75	0.8	208	3
	38-780			90	1.4	280	4
	37-850			132	2.0	350	4
	39-1000			200	3.0	450	4
	45-1250			250	4.0	450	5
	60-1250			320	5.0	450	5
	60-1500			2 x 400	6.0 – 7.0	450	5
	60-1500			2 x 500	7.0 – 8.0	450	5
ANDRITZ Feed & Biofuel	BioMax	Gear	ring	800	12	1200	3
	PM30	Gear		250-400	4-6	850	2
	LM26	V-belt		300	3-5	660	3
General Dies	EI20	-	ring	11 – 15	-	-	-
	CHI 3			37 – 55			
	ETA 36			55 – 75			
	TAU 4			75 – 132			
	DELTA 50			110 – 160			
	ALFA 56			132 – 200			
	OMEGA 67			132 – 250			
	C 88			2 x(132 – 200)			
La Meccanica	CLM 304 LG	V-Belt	ring	55	0.3-0.4	340	2
	CLM 420 HD LG			110	0.6-0.9	420	2
	CLM 520 HD LG			160	1.2-1.8	520	2
	CLM 630 G LG			200	1.8-2.5	630	2
	CLM 800 P LG			280	3.0-4.0	800	2
	CLM 935 LG			315	4.0-5.0	935	2
Demetra srl	Cub220-1	-	ring	9.2	0.14-0.15	220	2
	Cub220-2		ring	9.2x2	0.26-0.28	220x2	2x2
	Cub600-1		ring	30	0.45-0.46	600	2
	Cub600-2		ring	30x2	0.85-0.90	600x2	2x2

Table 23: Technical data of selected flat and ring die presses (continued)

Company	Press	Type of drive	Type of die	Drive power [kW]	Production capacity [t/h]	Inside diameter of die [mm]	Amount of rollers
SPC	PP150 Kompakt	Mechanic	Cylinder matrix	15	up to 0.125-0.175	280	2
	PP300 Kompakt		Cylinder matrix	30	up to 0.250-0.35	410	2
	PP450 Kompakt		Cylinder matrix	37	up to 0.4-0.5	410	2
	PP300 Twin		Cylinder matrix	2*30	up to 0.5-0.7	410	4
	PP450 Twin		Cylinder matrix	2*37	up to 0.8-1.0	-	4
Murska Oy Bio-pellets	Murska BK 350	belt	ring	30	0.4	350	2

Mobile pellets presses

Main disadvantages of alternative raw material are their low density and scattered availability making transportation less economic. Consequently, in the last years several companies offered mobile pellet units which are placed in containers. Due to economic reasons, such mobile pellet presses are mainly used in cooperation between several agricultural companies. All necessary production steps (grinding, conditioning, pelletising) are integrated in these mobile concepts. Thus, the relevance of logistic problems is much lower compared to stationary installed production plants even if only smaller amounts of raw materials are available. Several key actors have offered such applications on the market, see Table 24 and Figure 12 and Figure 13 for details.

Table 24: Technical data of selected mobile pellet presses

Mobile pellet mill	Press type	Transport of pellet mill	Drive power [kW]	Production capacity [t/h]	Raw materials
Germany					
PCM MPA 1000	Ring die	45“ High Cube Container Length: 13,7 m, Width: 2,43 m, Height: 2,90 m, Weight: 25 t	260	about 1.2	Straw, hay, Miscanthus and other raw material mixtures
Bauer Power	Flat die	Length: 12,20 m, Width: 2,75 m, Height: 2,90m, Weight: 19 t	144 - 158	1 – 1.5	Straw, hay, Miscanthus and other raw material mixtures
Finland					
Biobotnia Oy	Ring die	Length: 12,5 m, Width: 4 m, Height: 2,90 m Weight: 19,6 t	150	1.5 -2	Reed canary grass, straw, peat, wood and mixes
Sweden					
No mobile pellet presses available					
Austria					
No mobile pellet presses available					
Denmark					
No mobile pellet presses available					
Spain					
No mobile pellet presses available					
Italy					
General Dies	Ring die	Length: 1,9 m, Width: 1,6 m, Height: 1,85 m Weight: 1,6 t	55	0.5 - 0.6	Grapevine prunings, hay, other biomass

Since bales are different in form and size they are not suitable for all machines. It is difficult to grind wet fibres and also the quality of pellets is low. The soil of the fields can also be wet and heavy machines are difficult to move. The units are rather small and the best pelletising season is rather short, this can create economic problems. Co-operation is a solution to that. Furthermore, smaller mobile pellet machine presses can be connected to the PTO of the tractor. However, there are still some economical and technical issues to discuss and analyze and should be addressed for the different working conditions.

Figure 12: Pellet machine of Bauer Power (source: www.energievomland.de)

Figure 13: Mobile pellet mill of Biobotnia Oy (source: http://louhetar.fi/biobotnia/video).

Other press types

The PUSCH AG provides a comprehensive concept for the decentralized production of mixed biomass pellets from agricultural and woody raw materials. Based on the licensed concept "agrarSTICK®" different license holders are producing and marketing alternative pellets based on specific recipes. Therefore, these partners are provided with complete production, sales and logistics support based on a virtual trading platform for all internal and external business activities. Based on the „produced in and for the region" - philosophy, the agrarSTICK® will be distributed in the respective region. The pellet machine PM 5230 is an inhouse development of the Pusch AG which offers less work and cost intensive pretreatment of the raw materials. The production capacity is about 1,000 kg/h. The modular design provides an increase of the production capacity to a maximum of 4,000 kg/h. The benefits of the technology are:

- User-defined pellets from a mixture of raw materials can be produced.
- Raw materials with residual moisture up to 30 w. -% can be used.
- No additional grinding (e. g. hammer mill) or pre-treatment processes are necessary for raw materials with a length up to 5 cm.
- The production energy is reduced by an efficient plant technology.
- Rotating parts are not installed in dirty parts of the pelletising plant.

Figure 14: Pellet machine PM 5230 of Pusch AG (source: www.argarstick.de)

5.2.3 Costs of alternative and mixed biomass pellets production

Within the MixBioPells project the fuel costs have been calculated for selected case studies. More detailed information can be found in the Cost Analysis Report of the project. Fuel costs are determined by costs for crop growing, harvesting, transport (up to 50 km), drying and pelletizing/briquetting. As a major part of the annual running costs they have a wide influence on the economy of a heating system. Figure 15 presents the fuel costs identified in the different case studies in € / MWh considering these aspects. Furthermore the fluctuations of fossil fuel prices in the different partner countries are illustrated. The fuel costs amount to 18-56 € / MWh, depending on the used raw material and the pelletizing plant. Necessary pre-treatments of the raw material have a major impact on the pellet prices. Therefore raw materials which do not require intensive drying should be used.

→ **Low drying and storage costs are essential to ensure a profitable fuel.**

The costs for pelletizing and briquetting amount to 11-32 % of the whole fuel costs. Certainly, these costs strongly depend on the pelletizing/briquetting plant, but also on production parameters and fuel properties.

→ **Optimising the pelletizing process in terms of suitable production parameters and raw material mixtures is a large cost advantage.**

Due to the increasing prices of heating oil, the use of agricultural biomass fuels is getting more and more attractive from an economic point of view. Especially in the Nordic countries, the use of alternative biomass fuels is much cheaper than using fossil fuels. Even medium to large scale alternative heating appliances with flue gas treatment systems are more profitable over service life despite higher investment costs.

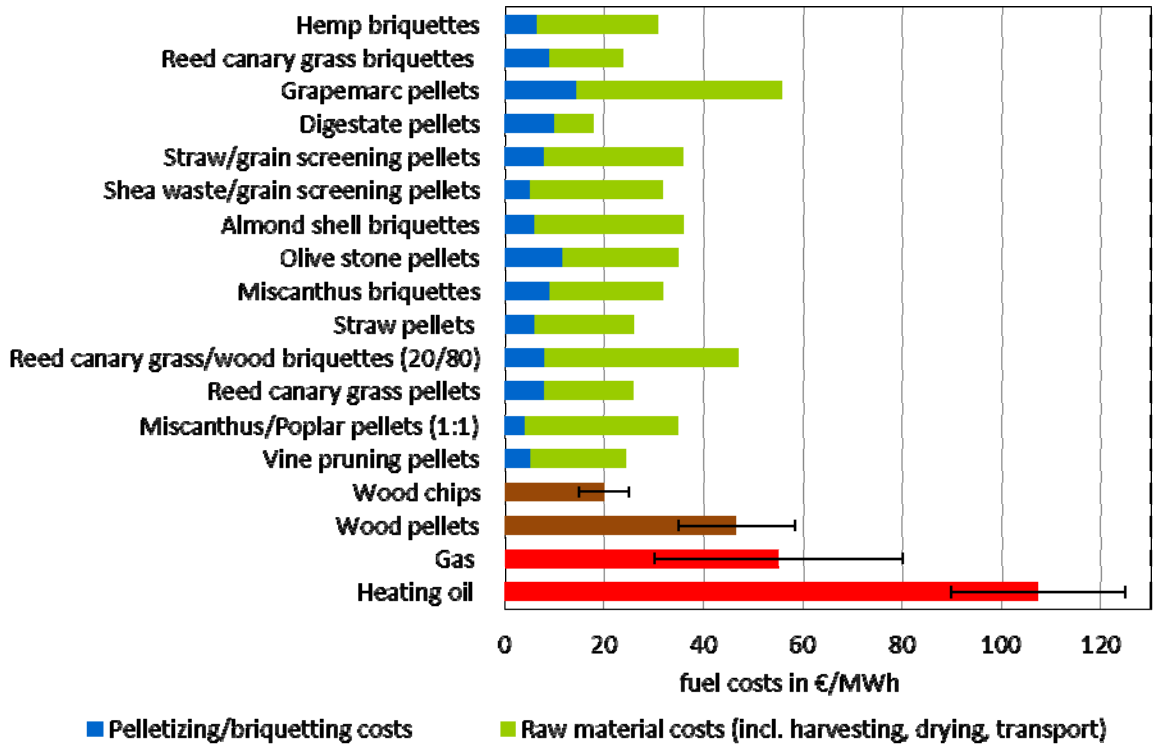


Figure 15: Fuel costs incl. costs of pelletizing and briquetting in €/MWh as well as fluctuations of wood and fossil fuel prices in the various partner countries

More detailed information can be found in the Cost Analysis Report /52/ of the project (www.mixbiopells.eu).

6 STORAGE OF PELLETS

Commonly commercially used pellets are put into retail bags (20 - 25 kg) in an automatic bagging machine or into big bags (1-1.5 ton). Usually retail bags are set on a palette and make a load of 1 ton. Besides that pellets can be store as bulk in silos or storage halls. They can be delivered as loose or pneumatic way to the storage of the user.

Durability of the pellets is a very important quality factor with regard to storage, transport, handling and combustion. The screening the pellets before delivery to the end-user will reduce the dust problems to some extent. Fines are also formed when pellets are dropped from the conveyor down to the pile/53/.

The amount of fines may accumulate under transport conveyors and may result in dust explosions. Moreover, risks for increasing emissions of particles, such as soot or even unburned material will appear/54/. Technical solutions in order to avoid fine particles may be to decrease the number of conveyors as far as possible and to keep the transport feed low.

Furthermore, prevention from self-heating and spontaneous ignition of bulk storages and from off-gassing of toxic emissions like carbon monoxide (CO) and volatile organic compounds (VOCs, e.g. aldehydes and low molecular carboxylic acids) must be considered. A number of incidents due to spontaneous ignition of wood pellets and accidents due to CO intoxication have been reported /55/, /56/.

Preventive measures can be:

- Install safety measures for existing facilities
- Education
- Ventilation
- Measurements (fixed installations and individual users)
- Personal protective equipment
- Install of warning signs at stores and confined spaces

In annex B4 key actors storage systems are listed.

7 COMBUSTION AND PRECIPITATOR TECHNOLOGIES

7.1 General

The combustion of alternative and mixed biomass pellets can be more challenging than the combustion of wood pellets and possible problems have to be considered. The reasons for this can be found in the composition of alternative raw materials that is significantly different from woody biomass.

Primary measures:

- modification of the fuel (leaching of the raw materials, blending of difficult raw materials with additives or less problematic raw materials) which can also enhance the ash related characteristics,
- modification of the combustion process (flue gas recirculation to achieve reducing atmosphere and lower temperature, cooled grates to reduce slagging, automated cleaning and ash removal to prevent slagging and fouling),

Secondary measures:

- flue gas cleaning.

7.2 Combustion technologies overview

7.2.1 Introduction to the combustion of alternative and mixed biomass pellets

The nature of the combustion process depends both on the fuel properties and the combustion application. The properties like elemental or molecular composition (e.g. porosity, fibroses, intact vs. destroyed cell wall structure) are inherent to the biomass feedstock. Thus, the term "fuel

composition related parameters" is used for such characteristics of the fuel. In contrast, there are adjustable process parameters (e.g. particle size, temperature, residence time) which can be set individually – although not always independently from other parameters – according to the requirements of a technical process. Nevertheless, these process related parameters are not always independently from each other. Thus, special focus should be taken on the influence of fuel composition related and especially process related parameters on thermo-chemical conversion processes. Compared to the combustion of woody biomass, the main fields of problems for the combustion of alternative and mixed biomass fuels are:

- Slagging tendencies in the bottom ash
- Increased emissions on dust, NO_x, HCl, SO_2
- Increased risks of corrosion and fouling

These problems can be lowered by primary and secondary measures. Reduction of harmful emissions through flue gases and effluents can be obtained by either avoiding creation of such substances (primary measures) or removing the substances from the flue gas (secondary measures). Primary measures are based on a modification of the combustion process and a secondary measure takes places after the combustion process. The main fields of problems for the combustion of alternative and mixed biomass fuels are summarised in Table 25.

Table 25: Main fields of problems for the combustion of alternative and mixed biomass fuels

Property	**Problems that might result from the property**
higher ash content	• problems with ash removal
varying fuel characteristics	• handling of these variations requires experience that is rarely available
higher content of critical elements (e.g. N, S, Cl, K, Na, Si)	• possibly higher emission of harmful gaseous components (e.g. HCl, SO_2, NO_x) and particulate • higher risk of fouling and corrosion on downstream tubes and surfaces • lower ash melting point with increased slagging risk

These problems can be lowered by primary and secondary measures. Reduction of harmful emissions can be obtained by either avoiding creation of such substances (primary measures) or removing the substances from the flue gas (secondary measures).

7.2.2 Primary emission reduction measures

Primary emission reduction measures aim to prevent or reduce the formation of emissions slagging tendencies and corrosion within the combustion chamber. Several possible measures exist that are on the one side the modification of the fuel composition and on the other hand the selection of the right combustion system. Both parameters must be fit together to achieve a reliable and stable combustion operation with low emissions. The main influences of the fuel properties on the combustion process are displayed in Figure 16.

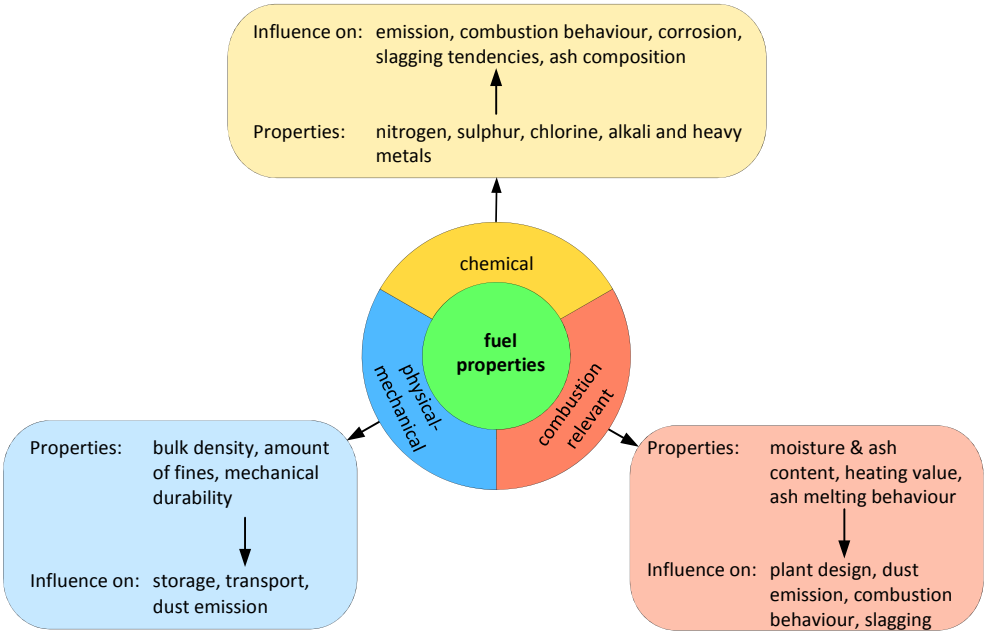


Figure 16: Impact of fuel properties on the combustion process (authors design)

Primary emission reduction measures aim to prevent or reduce the formation of emissions, slagging tendencies and corrosion. The most important issue is the limitation of critical elements. Using mixtures of different raw materials is one possibility to achieve the required fuel properties, e.g. of product standard EN 14961-6. The mixing ratio often depends on the availability and price of the raw materials. The following aspects are particular important /57/:

1. Good mixing of the component fuels is very important in order to ensure, for example:

- a stable combustion
- avoidance of local sintering
- adjustment of fuel properties resulting from the combination of different raw materials.

2. Raw materials that differ widely in particle size/form may require special treatment, such as milling or separate raw material feeding systems.

3. Wide differences in moisture content between the fuels may require special fuel feed arrangements.

Furthermore, the chemical composition of the used raw materials is of great relevance. As a general rule:

4. Fuels with high sulphur content, such as peat can improve the properties of fuels with high alkali contents.

5. Fuels with high ash melting points can improve the properties of agricultural fuels such as straw and grain screenings with low ash melting points.. However, ash related reactions are very complex. Thus, it is not always possible to predict the ash melting behavior in every case.

A very low proportion (< 2–3 wt.-%) of a "difficult" fuel added to a fuel mix that performs well does not normally cause problems. In some cases leaching, ideally by exposing the raw material to the weather for some time, can significantly reduce the content of critical component. Table 26 gives an overview about guiding values and guiding ranges for elements in biomass fuels and biomass ashes for unproblematic thermal utilisation that can be used as a basis for adjusting the right fuel mixtures. Biomass fuels within the given guiding concentration ranges can be used in modern combustion plants without problems. For fuels with compositions outside the given ranges, additional technological requirements should be considered with regard to national emission thresholds.

Table 26: Guiding values and guiding ranges for elements in biomass fuels and ashes for unproblematic thermal utilisation (according to "The Handbook of Biomass Combustion and Co-firing") /58/

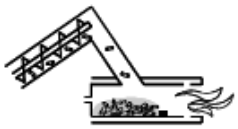
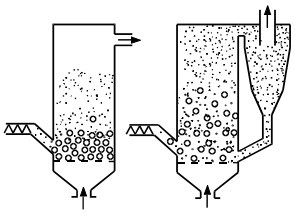
Critical element	Limiting concentration in the fuel, wt.-% (d.b.)	Limiting parameter	Raw materials that repeatedly break the limit	Technological measures to reduce critical impacts
N	< 0.6	NO_x emissions	Straw, cereals, grass, olive residues	Primary measures (air staging, reduction zone)
	< 2.5	NO_x emissions	Waste wood, fibre boards	Secondary measures (SNCR or SCR process)
Cl	< 0.1	Corrosion	Straw, cereals, grass, waste wood, olive residues	fuel leaching, automatic heat exchanger cleaning, coating of boiler tubes, appropriate material selection
	<0.1	HCl emissions	Straw, cereals, grass, waste wood	dry sorption, scrubbers, fuel leaching
	< 0.3	PCDD/F emissions	Straw, cereals, waste wood	sorption with activated carbon
S	< 0.1	Corrosion	Straw, cereals, grass, olive residues	See Cl / Corrosion
	< 0.2	SO_2 emissions	Grass, hay, waste wood	See Cl / HCl emissions
K	< 7.0 [1)]	Ash-melting point, depositions, corrosion	Straw, cereals, grass, olive residues	Against corrosion: see Cl / Corrosion
	–	Dust emission	Straw, cereals, grass, olive residues	Efficient dust precipitation, fuel leaching

1) of the ash; SCR…Selective catalytic reduction; SNCR…Selective non-catalytic reduction; d.b.… dry basis

7.2.3 Process related parameters

Parameters defined by the technical realisation of the thermo-chemical conversion such as residence time of the flue gas, temperature and mixing of the available oxygen with the flue gas usually not independent from each other. However, in cases where oxygen is available in sufficient quantities, temperature is the most important variable due to its exponential influence on the reaction rates. An optimization of these variables will in general contribute to reduced emission levels of all emissions from incomplete combustion. Hence, by optimizing any combustion process by adjusting the mixing of fuel and oxidant, temperature and residence time, emissions from incomplete combustion can be minimized. Thus, the selection of an appropriate combustion system is essential. Commonly available and appropriate combustion systems for the combustion of alternative and mixed biomass pellets are listed in Table 27 according to their thermal range.

Table 27: Combustion systems /6/

Combustion system	Thermal range	Picture
Horizontal stoker burner	20 kW – 1 MW	
Moving grate combustion system	30 kW – 10 MW	
Water cooled combustion chamber with ash stoker	50 – 800 kW	
Underfeed rotating grate combustion systems	3 – 20 MW	Not available
Fluidised bed firing (a) bubbling fluidised bed with lower gas flow and a defined boundary between the bed and the free board or (b) circulating fluidised bed with higher gas flow and a blurred boundary between the bed and the free board.	(a) 5 – 15 MW (b) 15 – > 100 MW	

Parameters defined by the technical realisation of the thermo-chemical conversion such as residence time of the flue gas, temperature and mixing of the available oxygen with the flue gas usually not independent from each other. However, in cases where oxygen is available in sufficient quantities, temperature is the most important variable due to its exponential influence on the reaction rates. An optimization of these variables will in general contribute to reduced emission levels of all emissions from incomplete combustion. Hence, by optimizing any combustion process by adjusting the mixing

of fuel and oxidant, temperature and residence time, emissions from incomplete combustion can be minimized. Thus, the selection of an appropriate combustion system is essential. Commonly available and appropriate combustion systems for the combustion of alternative and mixed biomass pellets are listed in Table 27 according to their thermal range. The combustion technology must be suitable to the problematic fuel properties. The technical requirements should apply to higher dust and NO_x-emissions, possible slagging tendencies and higher ash amounts. A powerful ash removal system combined with the possibility to control or limit of the combustion temperatures should avoid problems caused by slagging tendencies in the bottom ash. The reduction of dust emissions could also be realised by precipitators which are gaining more importance since more strict emission thresholds are coming into effect. Besides, the high investment and operation costs prevent a widespread usage of this technology in small and middle scale combustion systems so far. The operation with a suitable combustion system has to be achieved in any case. The following requirements could be necessary:

General technical requirements for the combustion systems:

- automatic ignition and fuel feed
- adequate possibilities to control the operation of the combustion system (power and combustion control), e.g. with staged combustion
- appliances for automatic (mechanically or pneumatically) cleaning of heat exchanger
- integration of the combustion system into peripheral systems (buffer storage etc.)
- operator convenience and maintainability

Technical requirements due to problematic fuel properties, when using fuels according to the ENagro label:

- reduction of dust emissions:
  - precipitators
- prevention or reduction of slagging tendencies in the bottom ash:
  - limitation of combustion temperatures in the fire bed due to air or water cooled combustion systems or control of temperatures in the combustion chamber
  - combustion systems with a powerful ash removal system suitable for the removal of ash agglomerates
- removal of higher ash amounts in the bottom ash:
  - combustion systems with a powerful ash removal system

7.3 Specific available combustion technologies and solutions in the selected European countries

Currently, high quality wood fuels are most often used in small heating systems. This fuel combines convient supply, easy handling and compliance with regulations even on small scale and with varying loads. Small heating-systems are mostly optimised for high quality wood pellets but there are innovations in the field of combustion technology to use alternative pellets as well. For example, in Austria burner and boiler manufacturers are working on solutions for mixed biomass combustion on

small scale. For some Scandinavian countries the capability to burn pellets with high ash content is claimed. Heating systems, like Guntamatic, REKA, Ökotherm or Hargassner, with capacities > 30 kW have been developed for the combustion of more problematic fuels than wood pellets and are gaining importance. Some woodchip boilers might be partly operated with alternative pellets. The combustion of alternative pellets is possible if the boilers are equipped with appropriate grate technology and operated with optimised parameters. Not all of these systems can handle all types of alternative pellets. Therefore, the standardisation and the adaption of the fuel and the boilers are of great relevance. Hence, the exact fuel specification of different boilers systems need to be known and communicated with pellet manufacturers and raw material suppliers. Especially, small scale combustion systems need to comply with higher dust emissions and have to cope with slagging and higher ash content. Several technologies for controlling and limiting of the combustion temperature to reduce slagging tendencies in the bottom ash are available on the market e. g. air cooled grate systems with moving grates or water cooled combustion chambers with ash stoker. A powerful ash removal system combined with the possibility to control the combustion temperatures should limit problems caused by slagging hazards. According to Table 28 about 90 % of the boiler manufacturers are producing combustion systems within a range up to several MW. In the range up to 300 MW there are fewer manufacturers which have long term experiences in the construction and operation of plants dealing with alternative or mixed biomass pellets or briquettes. Apparently, in Scandinavian countries the combustion of alternative and mixed biomass pellets is favoured in medium and industrial plants. In other countries e.g. in Germany and Austria the energetic utilisation in a range up to 1 MW is promoted due to economic or political constraints.

Table 28: Number of boiler and combustion plant manufacturers identified in the project selling combustion technologies for non-woody biomass; listing in accordance to the different thermal input ranges

	small scale < 100 kW	medium scale 100 kW - several MW	industrial scale up to 300 MW
Austria	3	7	0
Denmark	1	5	1
Finland	4	8	2
Germany	2	5	2
Italy	5	4	0
Spain	4	12	2
Sweden	4	4	2
Total	**23**	**45**	**9**

A list of manufacturers and contact details is included in annex B5.

Germany

In Germany, uncertainties concerning the allowed biomass fuels as well as unclear regulations to receive regulatory approval is of high relevance. According to Federal Immission Control Regulation No. 1 straw, whole plants (also pellets), grains (also pellets), energy grain processing residues, husks, culms residues and similar herbaceous biomass substances (like Miscanthus or hay)" and "other

renewable sources" can be used in small scale combustion plants without an individual approval. The classification of raw materials to the group "other renewable sources" leads to many uncertainties since an unclear defined measurement program and list of licensed fuels exists. Certain alternative raw material types are residues or even wastes according to the current legal framework. For several raw materials, the boundaries between waste and biogenic residues are not clear (e.g. allocation of apple pomace in Germany). For these raw materials, the combustion is particularly difficult since there are special regulations for waste incernation. To facilitate the use of these materials a clear regulation is required. This applies also the classification of mixtures with these raw materials. Thus, a small range of fuels can be used and strict emission thresholds for CO and dust exist in Germany for small combustion plants < 100 kW. Furthermore, only a few technical possibilities are available to keep the threshold values. Additionally, emission threshold values of HCl, NO_x and dioxins/furanes exist only in Germany for type testing. Due to the strict legal framework connected with many uncertainties, the combustion of alternative fuels is focussed on medium scale combustion systems for heat production. According to Federal Immission Control Regulation No. 4 straw and other herbal raw materials (e.g. cereal whole plant, grasses, Miscanthus) can be used in combustion plants > 100 kW after an individual approval by the local authorities. Due to logistic difficulties and insufficient support options, the use of alternative and mixed biomass pellets in big industrial CHP plants is very limited. Available small and medium scale combustion systems are approved for the following solid biofuels:

- ENplus - pellets
- ENplus pellets, other wood pellets (e.g. pellets according to EN 14961-2 class B) and non-woody biomass pellets
- Wood chips, ENplus pellets, non-woody biomass pellets

Additionally, combustion systems from 100 kW to several MW which are suitable for the combustion of wood chips, sawdust (and chipboards), non-woody biomass (pellets) are produced in Germany. Only a few German manufacturers of industrial scale combustion systems who commonly build grate and bubbling fluidised bed combustion systems are acting on the market. All German manufacturers distributing their technologies on European level. Especially Austrian manufacturers of small and medium combustion systems for alternative and mixed biomass pellets have several distribution partners in Germany. German manufacturers of combustion systems for the use of non woody and mixed biomass pellets are listed inTable 29.

Table 29: German manufacturers of boilers and combustion plants for non-woody and mixed biomass pellets

Company	Product	Technology	suitable fuels	Range of capacity [kW]
Heizomat	RHK-AK	Chain grate	1, 2, 3	30 – 850
Ökotherm	Compact	Water cooled combustion chamber with ash stoker	1, 2, 3, 4	49 – 800
Weiss Kessel-, Anlagen- und Maschinenbau GmbH	Push grate furnace	moving grate	3, 4, 5	650- 15,000
hs energieanlagen	BioCOM	Fluidised bed	3, 4, 5	2 - 100 MW

1 Miscanthus plellets based on ÖNorm C 4000
2 Woody biomass pellets based on ENplus
3 Wood chips based on ÖNorm 7133 A2 (ash content < 2 w.-%, d.b.)
4 Other non woody biomass pellets, e.g. straw, hay, bark
5 biogenic waste

Description of major available combustion technologies in small and medium scale in Germany

Ökotherm		
Contact details	A.P. Bioenergietechnik GmbH Träglhof 2 D-92242 Hirschau www.oeko-therm.net	
Type	Compact C0 - C8	
Range of capacity	49-800 kW_N	
Firing system	• Water cooled jacket with ash crusher	
Fuels	• Straw and hay pellets, rape press cake, cereal grains, Miscanthus, wood pellets, wood chips, horse manure, digestate	
Fuel supply	• Automatically with stoker	
Combustion air supply	• 2 speed-controlled air fans	
Ignition	• Hot air blower	
Combustion chamber	• Fire resistant refractory concrete and stainless steel parts • Horizontal installation	
Heat exchanger		
- Type	• Tube bundle heat exchanger	
- Installation	• Horizontal	
- Cleaning system	• Manually	
- Construction material	• No information available	
Ash removal	• Automatically with ash crusher in ash box	

Emission measurements (full load)

No.	*Source*	*Fuel*	*Type*
1	/2/	Wood pellets	Compact C0
2	/1/	Wheat straw pellets	Compact C0
3	/3/	Wheat straw pellets	Compact C0
4	/3/	Wheat straw pellets + 3 % molasses	Compact C0
5	/3/	Wheat straw pellets + 2 % limestone	Compact C0
6	/3/	Wheat straw pellets + 4 % limestone, + 3 % molasses	Compact C0
7	/3/	Wheat straw pellets + 6 % limestone, + 3 % molasses	Compact C0
8	/1/	Triticale whole plant pellets	Compact C0
9	/1/	Rape press cake pellets	Compact C0
10	/1/	Hay pellets	Compact C0
11	/2/	Rye / wood pellets (50/50)	Compact C0
12	/2/	Rye pellets	Compact C0
13	/4/	Reed cannary grass briquettes	Compact C2
14	/7/	Digestate pellets from biogas plant (input material: maize silage 50%, grass and grass silage 40%, potatoes 10%)	Compact C0
15	/7/	Digestate pellets from biogas plant (maize silage 81%, sugar sorghum/sudan grass silage 9%, poultry manure 7%, corn cob mix 3%)	Compact C0
16	/8/	Hay pellets	Compact C0
17	/8/	Hay pellets + 3% molasses	Compact C0
18	/8/	Hay pellets + 25% wood	Compact C0
19	/8/	Hay pellets + 50% wood	Compact C0

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions*)*

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	-	-	273	7	11	148	-	22	-	-
2		-	206	4.7	171	335	-	58	56	813
3	72.4	-	274.7	2.6	64.6	279.4	57.8	57.8	-	-
4	76.0	-	108.8	1.5	109.1	299.5	73.2	5.0	-	-
5	68.5	-	147.5	4.1	101.6	323.9	10.5	4.0	-	-
6	71.2	-	666.4	13.5	180.9	258.8	42.5	4.3	-	-
7	77.6	-	220.3	36.7	100.1	243.6	80.9	3.7	-	-
8		-	56	2	172	448		49	2	56
9		-	468	7.5	225	663		11	77	245
10		-	221	2	218	446		119	47	572
11	-	-	370	79	106	463	-	65	-	-
12	-	-	318	-	248	621	-	64	-	-
13	87	9,2	78	-	147	117	-	-	-	-
14	-	10,5	275 [1)]	-	100 (40 [1)])	334 [1)]	-	-	-	-
15	-	11,5	104 [1)]	-	106 (43 [1)])	398 [1)]	-	-	-	-
16	78.7	-	1853	7	767	497	14	8	-	-
17	79.4	-	1643	23	574	389	41	17	-	-
18	80.8	-	389	4	356	339	82	45	-	-
19	83.2	-	1349	6	366	272	38	26	-	-

[1)] With dust precipitator

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Heizomat		
Contact details	Heizomat GmbH Maicha 21 D-91710 Gunzenhausen www.heizomat.de	
Type	RHK AK	
Range of capacity	36-850 kW_N	
Firing system	• Chain grate system	
Fuels	• Wood chips	
Fuel supply	• Automatically with stoker and rotary gate valve	
Combustion air supply	• 2 speed-controlled air fans • 2 combustion air throttle valves (manually adjustable)	
Ignition	• Automatically with heating element	
Combustion chamber	• Cyclone combustion chamber • Fire resistant refractory concrete parts • Horizontal installation	
Heat exchanger - *Type* - *Installation* - *Cleaning system* - *Construction material*	 • Tube bundle heat exchanger • Horizontal • Automatically with turbulators • St 37.2 (thick-walled)	
Ash removal	• Heat resistant chain grate • 45, 270, or 900 l ash tonne	

mixBioPells
Market Implementation of extraordinary biomass pellets
Supported by:
Partner:

Emission measurements (full load)

No.	*Source*	*Fuel*	*Type*
1	/1/	Wood chips	RHK AK 50
2	/3/	Wood chips	RHK AK 50
3	/2/	Barley whole plant pellets	RHK AK 50
4	/1/	Wheat grains	RHK AK 50
5	/1/	Wheat grains + 2 % limestone	RHK AK 50
6	/1/	Wheat bran	RHK AK 50
7	/1/	Barley grains	RHK AK 50
8	/2/	Triticale grains	RHK AK 50
9	/3/	Wood chips / cereals (70/30) [1)]	RHK AK 50
10	/3/	Wood chips / cereals (75/65) [1)]	RHK AK 50
11	/2/	Rape press cake pellets	RHK AK 50

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions*)*

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	-	-	214	1	61	171	-	-	-	-
2	-	-	114	< 2.1	34	76	25	0.9	0.05	0.02
3	84.2	-	24	-	642	567	-	-	-	-
4	-	-	40	10	138	507	-	-	-	-
5	-	-	188	12	34	577	-	-	-	-
6	-	-	211	-	153	563	-	-	-	-
7	-	-	101	68	400	492	-	-	-	-
8	83.2	-	12	-	230	541	-	-	-	-
9	-	-	60	-	56	164	54	2.4	0.02	0.02
10	-	-	32	-	74	219	90	5.0	0.03	0.02
11	83.0	-	20	-	136	645	-	-	-	-

[1)] Cereals: mixture of 85% rye and 15% triticale

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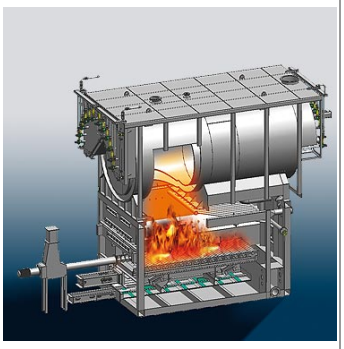
/7/ Heizomat GmbH: www.heizomat.de, 28.01.2009

Description of major available combustion technologies in industrial scale in Germany

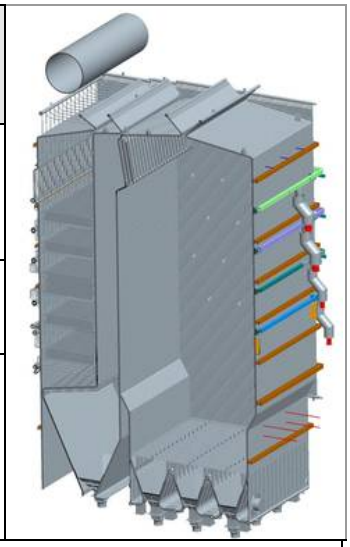
Weiss Kessel-, Anlagen- und Maschinen		
Contact details	Weiss Kessel-, Anlagen- und Maschinenbau GmbH Kupferwerkstraße 6 D-35684 Dillenburg-Frohnhausen www.weiss-kessel.de	
Type	Push grate furnace	
Range of capacity	0.65 - 15 MW	
Application	• Heat production, combined heat and power generation	
Firing system	• moving grate system	
Fuels	• Wood chips and dust • Wet grass • Bark with high ash content	
Fuel supply	• Automatically with stoker or hydraulic push in tappet for rough fuel	
Combustion air supply	• Primary and secondary air with air fans • Rezirkulation of the flue gas	
Combustion chamber	• cyclone-direct firing system with stepped combustion air furnace	
Operational characteristics	• No specification	
Ash removal	• wet respectively dry ash removal • The ash is transported with screws, scraper conveyors and conveying belts to the container and the ash bin. The filter de-ashing is a dry de-ashing system with container, big bags and silos.	

Emissions

- Results are commercially not available.

References:

/1/ www.weiss-kessel.de (17.01.2012)

h s energieanlagen gmbh		
Contact details	h s energieanlagen gmbh am Lohmühlbach 21 D-85356 Freising www.hsenergie.eu	
Type	BioCOM	
Range of capacity	2 - 100 MW	
Application	• Heat production, combined heat and power generation	
Firing system	• Fluidised bed combustion	
Fuels	• biomass • production waste • refuse derived fuel and sludge • biogenic residues, e.g. straw,	
Fuel supply	• depending on the physical cahracteristics of the fuel	
Combustion air supply	• Primary, secondary and tertiary air • Rezirkulation of the flue gas	
Combustion chamber	• Fluidised bed combustion system with temperature control by combustion air management (TopCOM)	
Operational characteristics	• Fuel input (LHV): up to 100 MW and 4 – 18 MJ/kg • Steam parameters: up to 120 bar, temperatures: 480/520°C	
Ash removal	• No specification available	

Emissions

BioCOM® boilers fully comply with the emission standards of the European Union (EU Guideline 2000/76/EG). The limitations are even under-cut considerably. This is based on project specific design of the fluidized-bed and the intelligent air level management TopCOM, which achieves an exact temperature control of combustion temperatures. Typical emissions according to manufacturer's data (11 Vol.-% O_2):

CO	< 5 mg/Nm³
NO_x	< 150 mg/Nm³
TOC	< 1 mg/Nm³

References:

/1/ www.hs-energie.eu (17.01.2012)

Austria

The energetic utilisation of solid biomass has a long tradition in Austria and is still a very important factor within the renewable energy sector. The very well documented wood pellet market developed with an annual growth rate between 30 and 40% until 2006. This development was then stopped 2006 due to a supply shortage which resulted in a substantive price rise. But meanwhile the production capacity of 21 Austria pellet manufacturers has been extended to 1.2 million tons a year and this resulted in a market recovery.

The market for biomass boiler has increased steadily from 2000 until 2006. A market break of more than 60% occurred 2007 with low prices for heating oil and the mentioned supply shortage of pellets. For 2008 the sales figures reached again the level of 2006. For 2010 a slight reduction of sales of pellets boilers about 4% was documented. The market break in all sectors of biomass boiler was due to several reasons like delayed impacts of the economic crisis, reduction of subsidies for biomass boilers and subsidies still given by the Austrian mineral oil industry for new oil boilers.

The Austrian market comprises of 8,131 pellet boilers, 6,211 wood log boilers and of 4,219 wood chip boilers for 2010 concerning the whole range of power. Furthermore 3,273 pellet stoves, 8,210 cooking stoves and 26,100 wood log stoves were sold. Austrian biomass boiler manufactures typically export approximately 70% of their production. In Germany for instance two out of three installed biomass boilers are of Austrian origin.

Regarding the production of mixed pellets no reliable market data exist. There are well developed production chains only for the purpose of material use. However, for fuel production no continuously operated productions are known. Alternative pellets are mainly produced by dedicated farmers, agricultural associations and cooperatives. However, they do not produce for commercial purposes. This is, amongst others, due to the uncertain legal framework.

There are some experience with pelletizing of straw, miscanthus and hay (see “Best practice examples”) in Austria. Furthermore, the association “Hay and pellets” have some experiences with pelletizing and combustion of hay and corn cobs in Styria. They have a pelletizing plant with a ring die technology and a production capacity of 800-1,000 kg/h. The pelletizing process begins with the bale breaker; afterwards the material is grinded by a hammer mill (4-6 mm). The pellets are stored in big bags.

Although the Austrian legal framework provide no type testing of furnaces which allow the use of such fuels, technology provider for combustion systems developed some products for the use of non-woody fuels. Compared to wood chips boilers, the main focus here is primarily on grate systems and ash handling technologies in order to cope with large amounts of ash and any resulting slagging.

Description of major available combustion technologies in small and medium scale in Austria

Hargassner		
Contact details	Anton Hargassnerstraße 1, A-4952 Weng; Tel.: +43-7723-5274 http://www.hargassner.at/	
Type	AgroFire	
Range of capacity	25 - 40 kW	
Firing system	• Moving grate system • Underfeed stoker	
Fuels	• Miscanthus pellets or brickets, • wood chips or pellets, • straw pellets, • energy grains	
Fuel supply	• Automatically with stoker • horizontal screw-conveyor	
Combustion air supply	• Primary and secondary air with air fans.	
Ignition	• Hot air blower	
Combustion chamber	• Fully refractory-lined combustion chamber	
Heat exchanger	• Water in tube heat exchanger • Air passes spirally	
- Type	• Tube heat exchanger	
- Installation	• vertical	
- Cleaning system	• automatically	
- Construction material	• No information available	
Ash removal	• Automatically with ash crusher in ash box	

Emission measurements (full load)

No.	*Source*	*Fuel*	*Type*
1	/2/	Wood chips	AGROFIRE 30

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions*)*

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	91.0	13	65	<1	20	151	-	-	-	-

References:

/1/ www.hargassner.at (09. 02. 2012)

/2/ Francisco Josephinum BLT: blt.josephinum.at, 09. 02. 2012

BIOKOMPAKT Heiztechnik GmbH		
Contact details	Froschau 79, A-4391 Waldhausen Tel.: +43-7260-4530 raimund.gerlinger@biokompakt.com http://www.biokompakt.com	
Type	BIOKOMPAKT® - AWK/ECO 65	
Range of capacity	23 – 66 kW	
Firing system	• Retorte firing system	
Fuels	• Wood chips and pellets • Energy grains • Rape pellets • Straw pellets • Grainy biomass	
Fuel supply	• Automatically with a screw-conveyor (wegen Retorte) • Different supply systems are available • different regulation systems are available	
Combustion air supply	• regulation of the primary and secondary air • flue gas ventilator	
Ignition	• automatically with hot air	
Combustion chamber	• ceramic chamber	
Heat exchanger		
	• vertical tube heat exchanger	
	• vertical	
	• no information available	
	• No information available	
Ash removal	• Into ash box	

Emissions

- Results are commercially not available.

References:

/1/ www.biokompakt.com (09. 02. 2012)

/2/ www.lenz-kg.de (09. 02. 2012)

Guntamatic Heiztechnik GmbH		
Contact details	Bruck7, A-4722 Peuerbach; Tel.: +43-7276-24410 http://www.guntamatic.com/	
Type	Powercorn 50 kW	
Range of capacity	12 – 50 kW	
Firing system	• Moving grate system	
Fuels	• Energy grains • Wood pellets	
Fuel supply	• From the channel to the combustion chamber with a screw-conveyor • Special systems for charging the channel • Automatically	
Combustion air supply	• Primary and secondary air is regulated with an ID-fan • Secondary air passes through a swirl nozzle	
Ignition	• Hot air blower	
Combustion chamber	• Stainless-steel chamber • Cyclone combustion	
Heat exchanger		
- Type	• Water in tube heat exchanger • Air passes spirally	
- Installation	• vertical	
- Cleaning system	• automatically	
- Construction material	• No information available	
Ash removal	• Ash screw–conveyor discharges the ash into the ash chest automatically.	

Emission measurements (full load)

No.	*Source*	*Fuel*	*Type*
1	/2/	Wood chips	Powercorn 50 kW

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions*)*

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	93.4	13	33	1	16	141	-	-	-	-

References:

/1/ www.guntamatic.com (09.02. 2012)

/2/ www.blt.josephinum.at (09.02. 2012)

Denmark

A wide range of renewable sources can be used for the energetic utilisation in combustion systems. In Denmark biomass is defined according to the Danish Act no. 638 of July 3 1997 on biomass waste. Any type of biomass or mix of biomass that is not mentioned in the annex to the act is defined as waste and must be handled and approved according to the EU Waste incineration directive in terms of temperature and retention time in an incineration plant. Furthermore, a waste tax is due. The following biomass is defined according to the Danish Act no. 638 of 03.07.1997:

- raw wood incl. bark, forest wood chips,
- clean wood including shavings and saw dust,
- wood waste from the production and treatment of clean laminated wood,
- straw,
- kernels and seeds from fruits and berries,
- fruit residues,
- nut and seed shells
- untreated cork, grain and seeds, cotton and flax,
- lolly sticks and green pellets (dried grass, clover etc.),
- malt, thatched roofing and tobacco waste,
- fuel pellets or fuel briquettes prduced exclusively from wastes.

The emission threshold values for the use of these materials in combustion plants are compiled according to the guidelines for Air Emission Regulation No. 1, 2002 and Act no. 808 of 25.09.2003 about emission from large plants Danish Environmental Protection Agency for Biomasses and the Danish Act no. 638 of 03.07.1997, Table 30.

Table 30: Emission thresholds according to the guidelines for Air Emission Regulation No. 1, 2002 and Act no. 808 of 25.09.200

Parameter	Thermal input / thermal output	Reference oxygen content O_2	CO	OGC	NO_x	SO_2	Particles
Unit	MW	%	mg/Nm^3				
Value	0.12-1.0	10	500	-	-	-	300
	1.0-50	10	625	-	300	-	40
	> 50 [1)]	6	-	-	300	200	30
	> 50 [2)]	6	-	-	600	400	100

1) New plant 2) Old plant

Danish manufacturers of combustion systems for the use of non woody and mixed biomass pellets are listed in Table 31.

Table 31: Danish manufacturers of boilers and combustion plants for non-woody and mixed biomass pellets

Company	Product	Technology	suitable fuels	Range of capacity
Twinheat	Combi	Horizontal stoker	Grain	29-80 kWth
Reka	HKRST	Grate	Straw, grain screenings	22-750 kWth
Linka	District heating	Water cooled chamber	Straw	1,5-10 MWth
Babcock & Wilcox Vølund	CHP	Vibrating grate	Straw, energy crops	10-170 MWth
B&W Scandinvian Contractors	CHP	Grate	Straw, energy crops	15-60 MWel
Weiss A/S	District heating	Grate	Straw, energy crops	0,5-20 MWth
Aalborg Energie Technic	CHP	Grate	Straw, animal litter	27-170 MWth

Description of major available combustion technologies in small and medium scale in Denmark

Reka		
Contact details	REKA A/S. Vestvej 7; 9600 Aars www.reka.com	
Type	HKRST	
Range of capacity	22-750 kWth	
Firing system	• Step grate	
Fuels	• Straw pellets, grain screenings, energy crops	
Fuel supply	• Automatically with auger	
Combustion air supply	• 2 air systems for primary air (grate) and secondary air (over fire)	
Ignition	• N/A	
Combustion chamber	• Water-cooled and fireproof refractory	
Heat exchanger		
- Type	• Three pass flue gas tubes	
- Installation	• Steel plate boiler	
- Cleaning system	• N/A	
- Construction material	• N/A	
Ash removal	• Automatically	

Emission measurements (full load)

No.	Source	Fuel	Type
1	/1/	Wheat straw pellets (8mm)	HKRST FSK 20
2	/2/	Wheat straw pellets	HKRST FSK 30
3	/1/	70/30 wood chips / wheat straw pellets (8mm)	HKRST FSK 20
4	/1/	50/50 wood chips / wheat straw pellets (8mm)	HKRST FSK 20
5	/2/	50/50 wood chips / wheat straw pellets (8mm)	HKRST FSK 30
6	/2/	50/50 rape press cake / wheat straw pellets	HKRST FSK 30
7	/4/	wheat straw pellets (12mm) + 1% $Al_2(OH)3$	HKRST FSK 30
8	/4/	Weizenstrohpellet (12mm) + 2% Kaolinite	HKRST FSK 30
9	/4/	wheat straw pellets (12 mm) + 1% CaO + 3% Melasse	HKRST FSK 30
10	/1/	Cereal grains	HKRST FSK 20
11	/3/	Rye grains	HKRST FSK 30
12	/2/	rape press cake	HKRST FSK 30
13	/2/	Miscanthus pellets	HKRST FSK 30
14	/3/	Straw pellets	HKRST FSK 30

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions*)*

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	-	-	144	-	224	688	213	-	-	-
2	81.3	-	199	1.1	231	251	223	67	-	-
3	-	-	149	-	58	750	51	-	-	-
4	-	-	110	-	49	566	106	-	-	-
5	90.0	-	190	2.2	233	292	289	45	-	-
6	84.7	-	114	1.8	372	642	493	34.9	-	-
7	-	10	2355	-	-	343	219	-	-	-
8	-	10	1276	-	-	363	278	-	-	-
9	-	10	123	-	679	372	197	-	-	-
10	-	-	1195	-	120	1088	449	-	-	-
11	-	-	1726	-	290	289	-	-	-	-
12	82.1	-	68	3.8	171	390	1169	33.8	-	-
13	82.6	-	64	3.3	230	299	113	47.6	-	-
14	-	-	2167	-	200	234	-	-	-	-

References:

/1/ Vetter A., Hering T., Peisker D.: Energetische Verwertung von Getreide und Halmgutpellets, Thüringer Landesanstalt für Landwirtschaft 2006, Jena

/2/ Kiesewalter S., Röhricht C.: Biomasseanbau und –verwertung als Energieträger/Humusstoff von flächen mit unterschiedlichem Schwermetallbelastungsgrad und Grünlandgebieten,

Schriftenreihe des Landesamtes für Umwelt, Landwirtschaft und Geologie Heft 30 2008, Dresden

/3/ Rationalisierungs-Kuratorium für Landwirtschaft (Hrsg.): Heizen mit Getreide 2, 2005, Rendsburg

/4/ Nikolaisen L.: Quality Characteristics of Biofuel Pellets, Danish Technological Institute 2002, Aarhus

/5/ Maskinfabrikken REKA A/S (Hrsg.): Betriebsanleitung Kesseltyp HKRST/V-FSK 20/30/60, 2001, Aars

/6/ Maskinfabrikken REKA A/S: www.reka.com, 27.01.2012

Italy

In Italy, the biomass fuels are defined by the Decree 152/06. In particular, combustion of chemically treated biomasses for energy use is allowed only in special power plants and under permission from the authorities. The Decree 152/06 fixes the emission limits of combustion plant. In several cases, the local authorities can reduce the national limits and even forbid the utilization of biomass for energy purposes in urban areas.

This uncertainty in the regulations, combined with the technical and economic difficulties of the production and combustion of high-density (pellets and briquettes) alternative biomasses, represent the main difficulties for the development of the sector. Currently, the energy related use of this type of products (different from pellet) is preferable in large power plants (> 20 MW thermal input), often mixed with woodchips, where it's possible to have low emission levels. Small power plants have difficulties in maintaining low emissions (without flue gas cleaning systems) especially for the dust emissions. Several boilers and stoves require certified pellet or, in general, pellets that meets certain specifications. Other boiler models are suitable for combustion both of pellets and wood chips.

There are few producers of alternative pellet boilers. In general, those boilers require multi-fuel, without any exact definition of the fuel to be used. Some of the burner manufacturers, specifically for agricultural pellets, optimize the system on the base of the type of pellet. At present, producers of large power plants fueled by alternative pellets are not known. The low availability of pellets made of agricultural residues or alternative raw materials combined with the economic uncertainty for its production don't motivate the industry to produce this kind of boilers.

Some of the main Italian manufacturers of combustion systems that use non-woody and mixed biomass pellets are listed inTable 32.

Table 32: Italian manufacturers of boilers and combustion plants for non-wood and mixed biomass pellets

Company	Product	Technology	suitable fuels	Range of capacity [kW]
Termocabi	Agripellet	Horizontal blow air burner	1	25 – 1000
Tatano	Kalorina pellet	Cochlea burner	1,2,3,4	20 - 116
Kondor	DC-AE	Cochlea burner	1,3,4,5	58-232
Termomeccanica Pisani	Caldaia biomasse	Cochlea burner	1, 3, 4, 5	29 – 350
FACI	Faci and Eco	Cochlea burner	1,3,4,5	26 – 287

1 Pellets and agripellets (generic)
2 Maize and cereals
3 Shells and husks
4 Olive cake
5 Olive stones

Description of major available combustion technologies in small and medium scale in Italy

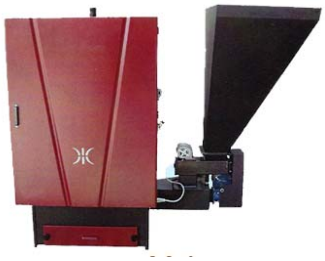
Termocabi		
Contact details	Via Borghisani n° 13 cap 26035, Pieve San Giacomo (CR) ITALIA Phone: 0372.640033 Fax: 0372.640354 E-Mail: termocabi@termocabi.it	
Type	NSE	
Range of capacity	25-1000 kW_N	
Firing system	Horizontal Blow air burner	
Fuels	• Agripellet	
Fuel supply	• Automatically	
Combustion air supply	• 2 speed-controlled air fans	
Ignition	• Electric Resistance	
Combustion chamber	• Fire resistant refractory concrete and stainless steel parts • Horizontal installation	
Heat exchanger		
- Type	• Tube bundle heat exchanger	
- Installation	• Horizontal	
- Cleaning system	• Manually	
- Construction material	• No information available	
Ash removal	• Automatically	

Emissions

- Results are commercially not available.

References:

/1/ www.termocabi.it, (09.02. 2012)

Kondor		
Contact details	KONDOR - S.S. 87 KM 180 — 86043 CASACALENDA (CB) TEL. +390874841541 FAX +390874841974 E-mail: info@kondorstufe.it	
Type	Serie DC-AE;	
Range of capacity	58 - 232 kW_N	
Firing system		
Fuels	• Pellets, husks, maize, olive cake, shells	
Fuel supply	• Automatically	
Combustion air supply		
Ignition		
Combustion chamber	• Cochlea burner	
Heat exchanger		
- Type		
- Installation		
- Cleaning system		
- Construction material		
Ash removal		

Emissions

- Results are commercially not available.

References:

/1/ www.kondorstufe.it (09.02. 2012)

TATANO		
Contact details	F.lli TATANO S.n.c. di Calogero Tatano Zona Industriale - 92022 Cammarata (AG)	
Type	Kalorina pellet – other models	
Range of capacity	20 - 116 kW_N	
Firing system		
Fuels	• Pellets, husks, maize, olive cake, shells of nuts, almonds, pistachio	
Fuel supply	• Automatically	
Combustion air supply		
Ignition	• Hot air blower	
Combustion chamber		
Heat exchanger		
- Type	• Tube bundle heat exchanger	
- Installation	• Horizontal	
- Cleaning system	• Manually	
- Construction material	• No information available	
Ash removal		

Emissions

- Results are commercially not available.

References:

/1/ www.tatano.com (09.02. 2012)

FACI		
Contact details	VIA FRASCA PADRE UGOLINO 66100 Chieti (CH)	
Type	FACI and ECO	
Range of capacity	26 – 287 kW_N	
Firing system	• Water cooled jacket	
Fuels	• Pellets, shells, olive cake and husks	
Fuel supply	• Automatically with stoker	
Combustion air supply	• 2 speed-controlled air fans	
Ignition	•	
Combustion chamber	• Cochlea burner system	
Heat exchanger		
- Type	• Tube bundle heat exchanger	
- Installation	• Horizontal	
- Cleaning system	• Manually	
- Construction material		
Ash removal		

Emissions

- Results are commercially not available.

References:

/1/ www.facicaldaie.com (09.02. 2012)

Sweden

Biomass as energy source has a long tradition and is widely accepted in Sweden. Use of processed biofuels (pellets, briquettes) has greatly increased in Sweden in recent decades, mainly to replace fossil fuels in large boilers, e.g. coal dust fired boilers. More recently, the demand from private households and residential heating systems has also increased, mainly due to conversion from fossil heating oil. This increased interest in pellets and briquettes for heating is beginning to cause a shortage of the traditional raw materials, sawdust and wood shavings, and therefore attention is turning to using a variety of agricultural products as raw material. In the future it is expected that /60/:

- The agricultural raw materials of greatest interest for large-scale production are pelletised Salix and reed canary-grass. They have competitive prices and acceptable fuel properties and could be mixed with sawdust in existing large-scale pelleting factories in Sweden.
- Straw has low production costs but can cause serious ash-related problems. Hemp has too high production costs to be of commercial interest, while distiller's waste and rape-seed meal currently have a higher alternative value when used as protein feed. Cereal screenings can be a

suitable raw material provided that they only make up a minor proportion in mixtures with other more problem-free raw materials.

- The scale of production has a great influence on production costs. In large-scale plants, the machinery and equipment, etc. are used much more efficiently than in smaller plants, which results in lower costs.
- Small-scale pelleting, both static and mobile, requires cheap raw materials and a high through-put to be profitable. In most cases, briquetting would be more commercially viable.
- The energy consumption in manufacturing pellets from dry agricultural by-products is generally no higher than when moist sawdust is used as the raw material. More energy is admittedly required for cultivation and transport of farm by-products, but since there is no need for drying the total energy consumption is often lower. However, wet raw materials such as fresh Salix and distiller's waste can increase the total energy consumption.

Description of major available combustion technologies in small and medium scale in Sweden

Hotab	
Contact details	Hotab Gruppen Hedentorpsvägen 16 291 62 Kristianstad
Type	Different types
Range of capacity	Small scale to medium scale
Application	The HOTAB Group's bio fuel plants contain their own designed system and products that are also sold separately. This can be fuel handling systems, exhaust gas purification and combustion furnaces. Furnaces up to 8 MW are constructed in one piece, brick-laid and dry-fired at HOTAB's own workshop. This is unique for HOTAB. The HOTAB Group builds plants within the capacity 0.5 – 16 MW for delivery of: - Hot water for district heating plants or for the process industry - Steam for the process industry - Hot air for drying purposes - Hot oil for the process industry or the ORC process
Firing system	With HOTAB's self-developed combustion technology a number of environmental advantages are obtained: - Very low emissions of CO and NOx - High combustion efficacy leaving a small part of non-combusted matter in the ashes - Low dust emissions.
Fuels	Pellets, wafers, woodchips, bark, sawdust, GROT (forestry residues), grain screenings, agro-pellets, refuse wood, energy forest products, energy crops.
Fuel supply	• Customized solutions
Combustion air supply	• Customized solutions
Combustion chamber	• Customized solutions
Operational characteristics	• Customized solutions
Ash removal	• Customized solutions

Emissions

- Results are commercially not available.

References:

/1/ www.hotab.se (09.02. 2012)

Baxi		
Contact details	Storgatan 50, 521 43 FALKÖPING Telefon: 0515-171 10 Fax: 0515-155 13 E-post: info@baxi.se	
Type	Different types	
Range of capacity	Small to medium	
Application	• Small to medium scale	
Firing system	• Customised	
Fuels	• Wood, peat, agricultural residues, energy plants	
Fuel supply	• customized	
Combustion air supply	• customized	
Combustion chamber	• customized	
Operational characteristics	• customized	
Ash removal	• customized	

Emission measurements (full load)

No.	Source	Fuel	Type
1	/1/	Industrial wood pellets	Multi Heat 2,5
2	/1/	Wheat straw pellets (8 mm)	Multi Heat 2,5
3	/2/	Wheat straw pellets	Multi Heat 2,5
4	/2/	Wheat straw pellets (gray)	Multi Heat 2,5
5	/2/	Wheat straw pellets + 50% rape press cake	Multi Heat 2,5
6	/1/	Wheat bran pellets (6 mm)	Multi Heat 2,5
7	/2/	Rape press cake	Multi Heat 2,5
8	/2/	Miscanthus pellets	Multi Heat 2,5
9	/1/	50/50 rye grain / wood pellets	Multi Heat 2,5

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions)

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	-	-	28	-	62	1125	24	-	-	-
2	-	-	310	-	273	662	125	-	-	-
3	-	-	113	1.9	143	767	57	16.4	-	-
4	-	-	185	21.2	-	450	347	41.7	-	-
5	-	-	67	37.4	146	1267	507	40.3	-	-
6	-	-	9	-	630	1040	206	-	-	-
7	-	-	1155	39.1	-	433	890	11.9	-	-
8	-	-	75	15.6	-	767	177	40.4	-	-
9	-	-	7	-	164	596	101	-	-	-

References:

/1/ Vetter, Hering, Peisker: Energetische Verwertung von Getreide und Halmgutpellets, Thüringer Landesanstalt für Landwirtschaft 2006, Jena

/2/ Kiesewalter, Röhricht: Biomasseanbau und –verwertung als Energieträger/Humusstoff von flächen mit unterschiedlichem Schwermetallbelastungsgrad und Grünlandgebieten, Schriftenreihe des Landesamtes für Umwelt, Landwirtschaft und Geologie Heft 30 2008, Dresden

/3/ BLT Wieselburg (Hrsg.): Prüfbericht Baxi Multi Heat 1.5, 2003, Wieselburg / Österreich

/4/ BLT Wieselburg (Hrsg.): Prüfbericht Baxi Multi Heat 2.5, 2003, Wieselburg / Österreich

/5/ Baxi A/S (Hrsg.): Produktinformation Multi Heat, Tarm / Dänemark, 2003

/6/ Baxi A/S (Hrsg.): Bedienungsanleitung für Montage und Betrieb des HS-Tarm Typ Mulit-Heat, Tarm / Dänemark, 2003

/7/ Baxi A/S: www.baxi.dk, 29.01.2012

SWEBO Bioenergy		
Contact details	Swebo Bioenergy Bullerleden 7 961 67 Boden Tel: 0921-578 00 Fax: 0921-176 73 http://www.swebo.com/foeretag.html	
Type	Multi burner	
Range of capacity	80 to 1000 kW	
Application	Among other fuels, the burner can burn challenging fuels such as horse and chicken manure, extremely moist chips (with a moisture content of up to 61%), offal, etc. In other words, it is a genuine multi-burner.	
Firing system	Multi burner, burner is available in both single and double design versions	
Fuels	Examples of compatible fuels: - Horse manure (moisture content up to 50%) - Moist wood chips (moisture content up to 61%) - Waste pellets - Traditional pellets - Harvesting residue - Offal, etc.	
Fuel supply	Different solutions	
Combustion air supply	Secondary air is preheated to 400 degrees to achieve maximum capacity. Combustion temperature in the secondary pipes/SCC approx. 1,100 degrees	
Combustion chamber	The SWEBO BioTherm is designed to operate with most existing bioenergy boilers. The SWEBO BioTherm is available in single or double module versions. Its flexible design allows one of the modules to be serviced without the need to shut down the system. Combustion temperature in the combustion chamber approx. 850 degrees	
Operational characteristics	SWEBO Backup - automatic backup function with pellets that automatically comes into force unless the manure can be fired or if it runs out.	
Ash removal	The SWEBO BioTherm uses a feed screw to transport residues out of the burner and into a storage chamber, usually located outside the installation for easy emptying. The ash feed screw is dimensioned for industrial use to ensure long-lasting, safe operation. Also available with automatic ash removal if desired.	

Emissions

- Results are commercially not available.

References:

/1/ www.swebo.com/en/companies/products/burner/horse-manure-burner/swebo-biotherm.html (29.01.2012)

Spain

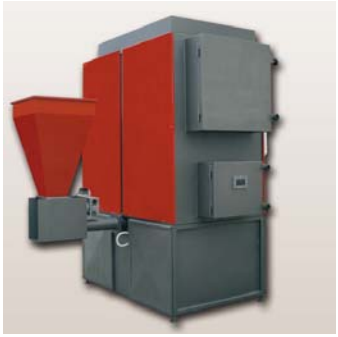
In Spain there are about 18 companies manufacturing boilers suitable for alternative and mixed biomass pellets. Though there are only a few Spanish companies in the field of biomass pelletising there is some experience available for the combustion of alternative biomass (mostly agro residues, e.g. olive stones, almond shells). However, main focus of all available boilers is the suitability for alternative biomass but not the comfort for the end user nor emission thresholds or efficiency. Thus, available boilers are rarely equipped with grate cooling to avoid slagging or automated cleaning and ash removal to handle the larger ash content of alternative biomass. The 18 companies are specified in Table 33.

Table 33: Spanish manufacturers of boilers and combustion plants for non-wood and mixed biomass pellets

Company	Power range	Website	Location
ANINGAS, S.A.	> 200 kW	www.aningas.com	BARCELONA
CALDERES CAÑELLAS, S.L.	> 200 kW	http://webfacil.tinet.org/calderasbiomasa.net	TARRAGONA
INNOVACIONES METACALORIFICAS, S.L. [INMECAL]	< 200 kW	www.inmecal.com	HUÉTOR TÁJAR
INDUSTRIAS DE LA ROSA, S.L.	> 200 kW	www.industriasdelarosa.com	MONTORO
ERATIC, S.A.	> 200 kW	www.eratic.es	QUART DE POBLET
FACODY, S.L.	< 200 kW	www.facody.com	ZARAGOZA
INDUSTRIAS HERGÓM, S.A. [HERGOM ALTERNATIVE]	> 20 kW	www.hergomalternative.com	SANTANDER
JUAN COSTA RAMISA	> 200 kW	www.incoszonda.com	MANLLEU
LASIAN TECNOLOGÍA DEL CALOR, S.L.	> 20 kW	www.lasian.es	MUEL
ASPIRACIONES ZAMORANAS MIZ, S.A.	> 200 kW	www.aspiracioneszamoranas.com	MORALES DEL VINO
OPTI THERMAL, S.L.	> 200 kW	www.optithermal.com	RIBARROJA
INSTALACIONES MORAL Y LOPEZ, S.A	< 200 kW	www.moralylopez.com	ÚBEDA
RCB [TALLERES RAFAEL CUBELS BALLESTER, S.L.]	> 200 kW	www.calderasrcb.com	CATARROJA
SUGIMAT, S.L.	> 200 kW	www.sugimat.com	QUART DE POBLET
CASA TABARÉS, S.L.	< 200 kW	www.casatabares.com	ÍSCAR
TOSCOARAGONESA, S.A.	< 200 kW	www.tosco-aragonesa.es	AZAILA
TUBOCÁS, S.L.U.	> 200 kW	www.tubocas.net	CASTILLEJAR
VULCANO SADECA, S.A.	> 200 kW	www.vulcanosadeca.es	MADRID

Mostly boilers of more than 200 kW are produced in Spain.

Description of major available combustion technologies in small and medium scale in Spain

HERGOM ALTERNATIVE		
Contact details	Industrias Hergóm, S.A. Soto de la Marina. Cantabria. España Tel.: +34 942 587 000 Fax.: +34 942 587 001	
Type	Oliva, Forestal, Sirocco	
Range of capacity	28-1163 kW	
Firing system	Cast iron burner	
Fuels	All crushed fuels (Pellet,olive residues,shells,firewood)	
Fuel supply	Automatically with double fall-back auger	
Combustion air supply	Automatic controlled air fan. Manual valve for secondary air	
Ignition	Automatically with heating element	
Combustion chamber	three flow passages, The heat exchanger is made of iron seamless smoke tubes inmersed into the water and placed in the upper part of the combustion chamber.	
Heat exchanger *- Type* *- Installation* *- Cleaning system* *- Construction material*	• iron seamless smoke tubes • Horizontal • Automatically with turbulators • Iron seamless	
Ash removal	Manual or automatic into an ash box	

Emissions

- Results are commercially not available.

Fuel characterization

- Olive Stone (N: 1.81 C:46.55 S:0.11 H:6.33 O:45.20 wt.-%) Higher Heating Value (HHV): 17,884 J/g
- Almond Shell (N:0.30 C:46.35 S:0.22 H:5.67 O: 47.20 wt.-%) HHV: 18,275 J/g

References:

/1/ García, R., Pizarro,C., Lavin,A.G., Bueno, J.L., Characterization of spanish biomass wastes for energy use. Bioresource Technology 103 (2012) 249-258

/2/ Hergom Alternative, www.hergomalternative.com, 30.03.2012

Carsan-Inmecal		
Contact details	Polígono Industrial "La Catalana" Calle Austria, 23. 18360, Huétor Tájar. GRANADA. Telf.: 958 333 789. Fax: 958 333 589. Email: info@inmecal.com	
Type	DINAMIC	
Range of capacity	28-85 kW	
Fuels	Wood pellet and olive stone	
Fuel supply	Automatic via suction.	
Ignition	Automatic	
Combustion chamber	3 way system Circular secondary air supply	
Heat exchanger *- Type* *- Installation* *- Cleaning system*	• Vertical pipe-heat exchanger • Horizontal • Automático	
Ash removal	A external box, controled	

Emissions

- Results are commercially not available.

Fuel characterization

- Results are commercially not available.

References:

/1/ www.carsanbio.com, 30.03.2012

LASIAN		
Contact details	Polígono Industrial Las Norias, parcela nº 7 50450 - Muel (Zaragoza) Tel: 976 140 600 Fax: 976 140 522 info@lasian.es	
Type	BIO-SELECT, BIOMAX	
Range of capacity	35-65 kW	
Fuels	Cualquier tipo de biomasa sólida (1)(2)	
Fuel supply	Direct auger, optional suction	
Combustion air supply	Air blowers	
Ignition	Manual o automática	
Combustion chamber	Cuerpo de acero	
Heat exchanger *- Type* *- Installation* *- Cleaning system* *- Construction material*	• Vertical heat exchanger • Horizontal • Automatic	
Ash removal	Box with a capacity of 96 kg	

Emissions

- Results are commercially not available.

Fuel characterization

- Max size of fuel 40 mm, min. 3100 kcal/kg and moisture content 10 and 12 wt.-%
- Fuels: olive stones and other residues from olive processing, saw dust, almond shells,…

References:

/1/ www.lasian.es, 30.03.2012

PAMER		
Contact details	Instalaciones Moral y López, S.A. - Polígono Industrial "Los Cerros" - C/ Artesanía, 14-16 - 23400 Úbeda (Jaén) - Tfno.: 953 75 30 45 info@moralylopez.com	
Type	MLVR	
Range of capacity	232 a 1744 kW	
Application	Agroindustry	
Firing system	Grate.	
Fuels	Olive residues, almond shels	
Fuel supply	With auger from"day hopper" tank attached to the boiler.	
Combustion air supply	With electrical blowers which adapt to the fuel input automatically	
Combustion chamber	Cilindrical, horizontal	
Operational characteristics	Manual filling of a 300 kg tank at the boiler. From there the fuel is transported with an auger to the combustion chamber. Manual ignition.	
Ash removal	Manual	

Emissions

- Results are commercially not available.

Fuel characterization

- Max size of fuel 40 mm, min. 3100 kcal/kg and moisture content 10 and 12 wt.-%
- Fuels: olive stones and other residues from olive processing, saw dust, almond shells,…

References:

/1/ http://moralylopez.com/index.php?option=com_content&view=article&id=11&Itemid=4, 30.03.2012

Description of major available combustion technologies in industrial scale in Spain

SUGIMAT		
Contact details	Sugimat SL c/ Colada d'Aragó s/n Quart de Poblet (Valencia) 46930 ESPAÑA Tlf: 961597230 Fax: 961920026 e-mail: sugimat@sugimat.com	
Type	STA, STAH	
Range of capacity	0.35 a 15 MW	
Application	Industries with wood or agro wastes	
Firing system	Vertical flow chamber	
Fuels	STA: damp marterial (saw dust, bark, wood chips,…) STAH: dry materials (saw dust, wood chips, Cork,…)	
Fuel supply	Automatic via conveyor belts and auger	
Combustion air supply	Air Blowers	
Operational characteristics	Can heat water or oil, for higher temperatures	
Ash removal	Semi Automatic	

Emissions

- Results are commercially not available.

Fuel characterization

- Results are commercially not available.

References:

/1/ www.sugimat.com, 30.03.2012

Finland

In Finland there are several experienced boiler manufactures from small scale to large CHP-systems that can be operated with alternative and mixed biomass pellets, Table 34. Most of the technology is traditional, but there are also new kind boilers and burners. Ariterm Oy has a moving grate even in rather small burners (40 kW) and Metso Power Oy a horizontal "rotating" grate in their smaller boilers (3-25 MW). Fluidised bed combustion is done by using several technologies in the capacity range of 2 -300 MW. It has been built and researched the use heating systems with difficult fuels. Last years also gasifying has been used different fuels even straw and reed canary grass pellets.

Table 34: Burner and boiler manufactures in Finland

Manufacturer	Address	Website	Remarks
Ariterm Oy	Uuraistentie 1, 43101 SAARIJÄRVI	www,ariterm.fi	small and middle scale pellets burner, up to 2 000 kW.
Oy Nord Mills Ltd	Pirttisentie 224, 62435 PIRTTINEN	www.nordmills.fi	small scale pellets burner <100 kW
Tulosteekniikka Oy	Pietari Brahentie 24, 43700 KYYJÄRVI	www.tulostekniikka.com	500 – 5000 kW heating systems
Nakkilan Boilers Oy	Villiläntie 2, 29251 NAKKILA	www.nakilagroup.fi/	large boilers
MW Power Oy	Ratapihankatu 53 A 20100 TURKU	www.mwpower.fi/	boilers
Renewa Oy	Teknobulevardi 3, 01530 VANTAA,	www.renewa.fi/en/	boilers, fluidised bed
Vapor Finland Oy	Messipojantie 20, 90520 OULU	www.vapor.fi	boilers, fluidised bed
Metso Power Oy		www.metso.com/corporation/	power stations 3 MW to big CHPs
Foster Wheeler Energia Oy	Relanterinkatu 2, 78201 VARKAUS	www.fosterwheeler.fi	big CHP-systems

Description of major available combustion technologies in small and medium scale in Spain

Ala-Talkari		
Contact details	Veljekset Ala-Talkkari Oy Hellanmaantie 619 FI-62130 Hellanmaa www.ala-talkkari.fi/	
Type	Veto 500	
Range of capacity	10 - 500 kW_N	
Firing system	Water boiler with automatic feeding system (stoker)	
Fuels	• Wood chips, Wood- and peat pellets, Miscanthus, Straw and hay briquets and pellets, grain, rape press cake,	
Fuel supply	• Automatically with stoker	
Combustion air supply	• Lambda steered, frequency inverted,	
Ignition	• Hot air blower	
Combustion chamber	weather proof steel, vertical installation,	
Heat exchanger		
- Type	• Tube bundle heat exchanger	
- Installation	• Vertical	
- Cleaning system	• automatic ,pneumatic	
- Construction material	• steeltube	
Ash removal	• Automatically with ash auger in ash box	

Emission measurements (full and 30% load)

No.	*Source*	*Fuel*	*Type*
1	/2/	Wood chips	Veto500
2	/2/	Wood chips	Veto500

Emissions according to source (based on 13 Vol. - % O_2 at standard conditions)

No.	η_{boiler}	O_2	CO	C_xH_y	$Particles_{total}$	NO_x	SO_2	HCl	PAK	PCDD/F
	%	Vol. – %	mg/Nm³						µg/Nm³	pg TE/Nm³
1	90.4	8.0	139	1	49	144			-	-
2	91.4	11.5	493	2	49	117			-	-

2) based on 13 Vol. -% O_2 at standard conditions

References:

/1/ Bayer-Beck, J. & Hegebart, M., 2011. Auftrag des Eigenbetriebes Umwelttechnik der Stadt Baden-Baden vom: 02.02.2011, Messungen im Abgas der Verbrennungsanlage der Fa. ALA TALKKARI in Öbisfelde. Baden-Baden. Eigenbetrieb Umwelttechnik der Stadt Baden-Baden. 11 p.

/2/ Birnbaum, T., 2010. Aufnahme der Emissions- und Leistungscharakteristik einer Kesselanlage nach EN 303-5. Dresden. Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH. 31 p. + App. 14 p.

/3/ Bayer-Beck, J. & Hegebart, M., 2012. Auftrag des Eigenbetriebes Umwelttechnik der Stadt Baden-Baden vom: Messungen im Abgas der Verbrennungsanlage der Fa.ALA TALKKARI in Sinzheim Kläranlage. Baden-Baden. Eigenbetrieb Umwelttechnik der Stadt Baden-Baden. 13p.

Biofire Oy		
Contact details	Biofire Oy Nummijärventie 479 FI-61910 Nummijärvi	
Type	Biofire Palokärki 30, 35, 35T, 50 50T	
Range of capacity	30-50 kW	
Firing system		
Fuels	Wood pellets, peat pellets (T-model), corn	
Fuel supply	From the fuel silo with a transport screw to the rotary feeder of the burner. From which the fuel drips on the drive auger, which pushes fuel to the burner head and pushes the ash the ash chamber of the boiler. Logic-controlled.	
Combustion air supply	Air fan with variable control	
Ignition	Manual	
Combustion chamber	Heat-resisting steels, round or oval	
Heat exchanger		
- Type		
- Installation		
- Cleaning system		
- Construction material		
Ash removal	Boilers can be equipped with automatic ash removal and soot sweeping.	

References:

/1/ www.biofire.fi/@Bin/137686/30-50kW+Palok%C3%A4rki+Pellettiesite+01-12.pdf

Biofire Oy		
Contact details	Biofire Oy Nummijärventie 479 FI-61910 Nummijärvi	
Type	Ceramic pellet burner of Biofire	
Range of capacity	Max. power 60-2000 kW	
Firing system		
Fuels	Wood pellets, peat pellets, corn, mixed pellets	
Fuel supply	From the fuel silo with a transport screw to the rotary feeder of the burner. From which the fuel drips on the drive auger, which pushes fuel onto the burner head. Automatic grate aggregate distributes fuel on the grate and removes ash to the ash chamber of the boiler. 2-variable power levels and the stepless adjustment after the power requirement. Logic-controlled.	
Combustion air supply	With the air blowers, the air of combustion is divided into different sections. Variable logic controls of the airflow.	
Ignition	Manual or automatic	
Combuston chamber	Grate of the cast iron, ceramic sides and roof stones	
Heat exchanger		
- Type		
- Installation		
- Cleaning system		
- Construction material		
Ash removal	Boilers can be equipped with automatic ash removal and soot sweeping.	

References:

/1/ www.biofire.fi , 09.02.2012

Ariterm		
Contact details	Ariterm Oy Box 59 43101 Saarijärvi Finland www.ariterm.fi	
Type	Arimax Bio	
Range of capacity	120-3000 kW_N	
Firing system	• Water cooled BioJet burner or Moving grate MultiJet burner	
Fuels	• Straw and hay pellets, cereal grains, Miscanthus, wood pellets, wood chips, peat and peat pellets	
Fuel supply	• Automatically with feeder and screws	
Combustion air supply	• frequency converter controlled air fans	
Ignition	• Hot air blower	
Combustion chamber	• Fire resistant ceramic and steel	
Heat exchanger		
- Type	• Vertical heat exchanger	
- Installation	• Horizontal	
- Cleaning system	• Automatic	
- Construction material	• No information available	
Ash removal	• Automatically with ash screw	

References:

/1/ www.aritherm.fi, 09.02.2012

7.4 Combustion technologies overview

7.4.1 Introduction

According to the main fields of problems for the combustion of alternative and mixed biomass fuels secondary measures may be necessary, depending on the elementary composition and the fuel characteristics of the selected biomass fuel, and the combustion technology to reduce hazardous emissions. Emission reduction measures primarily for removal of particles, NOx and SO_2 are needed. Other components that can also be reduced by secondary measures are HCl, heavy metals and PCDD/F. However, secondary emission reduction measures are known and are available for all harmful emission components; it merely depends on emission limits, the range of capacity and cost-effectiveness whether the emission reduction measures can be implemented or not. By increasing the size of the biomass combustion applications, improved emission reduction possibilities will become cost-effective.

7.4.2 Specific available technologies and solutions for small and medium scale combustion systems

For small and medium scale combustion the reduction of small particle emission will probably be most critical. There are two different approaches for the reduction of particulate emissions:

- Many boiler manufacturers focus their developments on the optimisation of the combustion chamber as well as the fuel and air supply.
- Another possibility is the use of precipitator technology

Especially in small and medium combustion systems dust precipitators are only partly available on the market or subject of several ongoing research activities. Mainly, the separation efficiency depends on the particle size distribution and the precipitator technology. The high specific investment and operation costs prevent the widespread usage of the technology and cause a low demand though there is a limited number of applications in a range of capacity < 100 kW_{NWL} is available on the market. Not every particle control technology suits every need. Among the determining factors are the particle's size, required collection efficiency, gas flow size, maintenance effort, the detailed nature of the particles, and the presence of tars in the flue gas. The following rules of thumb may be helpful in selecting particle control technologies for biomass combustion applications /58/:

- Sticky particles (e.g. tars) must be collected in a liquid, as in a scrubber, or in a cyclone, bag filter or an electrostatic filter whose collecting surfaces are continually coated with a film of flowing liquid. There must also be a way to process the contaminated liquid thus produced.
- Particles that adhere well to each other but not to solid surfaces are easy to collect. Those that do the reverse often need special surfaces, e.g. Teflon-coated fibres in filters that release collected particles well during cleaning.
- The electrical properties of the particles are of paramount importance in electrostatic filters, and they are often significant in other control devices where friction-induced electrostatic charges on the particles can aid or hinder collection.
- For non-sticky particles larger than about 5mm, a cyclone separator is probably the only device to consider.
- For particles much smaller than 5mm one normally considered electrostatic filters, bag filters and scrubbers. Each of these can collect particles as small as a fraction of a micron.
- For large flows the pumping cost makes scrubbers very expensive; other devices are preferable.
- Corrosion resistance and dew point must always be considered.

The effectiveness of particle precipitators is displayed in Figure 17.

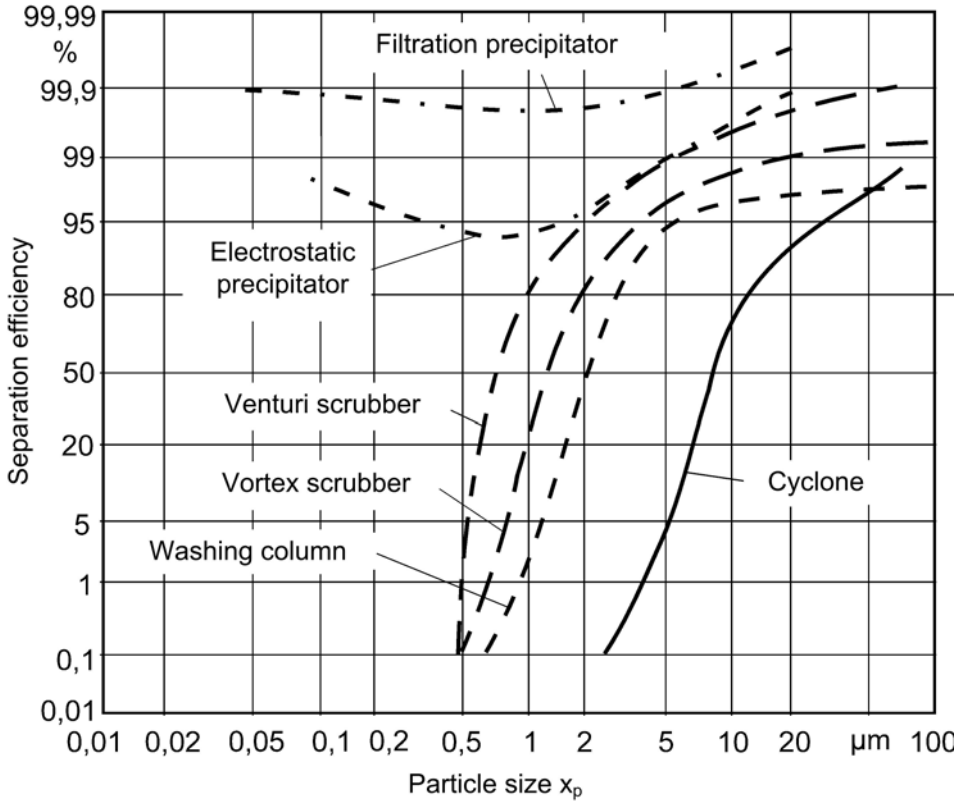


Figure 17: Separation efficieny of different precipitators (modified) /6/

Obviously, the separation efficiency strongly depends on the particle size. In the following available particle technologies are listed according to different range of capacities and types of precipitators:

- Flue gas condensation systems / scrubbers
- electrostatic precipitators
- filtration systems
- precipitator technologies using centrifugal forces

Until the end of the 1990s, precipitator technologies were used almost exclusively within a capacity range above 1 MW in industrial combustion plants. Especially in the last years, the public perception and the discussions in policy were more and more focussed especially on the risks of particulate emissions. In the consequence stricter emission thresholds for small scale combustion appliances were set especially in Austria and Germany.

Actually, electrostatic precipitators as well as flue gas condensation systems are commonly available and used. Nevertheless, most of the available systems have not the same high separation efficiencies compared to the industrial applications. Further optimisation for the automatic cleaning of the precipitators will be done in the future. So far, filter precipitators are not offered for heating appliances with a capacity range < 100 kW/59/.

The used precipitator systems are developed for the use of woody biomass in stoves and boilers. Some of these systems are tested for the use non-woody and mixed biomass and were adapted to some extend for higher dust concentrations and varying dust characteristics compared to woody biomass. Most of the manufacturers of precipitator technologies are located in Germany and to some extend Austria, Switzerland and Norway. Thus, a country specific description is not useful. In the following available technologies are summarized in the technology descriptions according to the precipitator types. For each type of precipitator representative technology descriptions are included.

A list of manufacturers and contact details is included in annex B6.

Technology descriptions of electrostatic dust precipitator technologies

Spanner Re^2 SF		
Company	Spanner Re^2 GmbH Niederfeldstr. 38 84088 Neufahrn / Deutschland www.spanner.de	
Type	SF	
Range of performance	SF 20 < 30 kW_N SF 50 < 80 kW_N	
Fuels	• Wood pellets and chips • Wood logs • Straw • Cereals • Miscanthus	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• approx. 1500 € (SF 20) • approx. 3000 € (SF 50)	
Basic technological data	• tube type electrostatic precipitator • additional flue gas fan integrated in order to handle pressure drop • voltage power supply: 15 kV • power consumption during operation: 30 kW	
Field of application	• automatic wood pellet and wood chip boilers • wood log boiler	
Separation efficiency by using woody biomass by using non-woody biomass	 • between 60 and 70 % (mean value) • No specification available	

References

[1] Spanner Re^2 GmbH (Hrsg.): Prospekt Partikelabscheider Spanner-Feinstaub-Filter, 2008, Neufahrn / Deutschland

[2] Spanner Re^2 GmbH (Hrsg.): Flyer Partikelabscheider Spanner-Feinstaub-Filter, 2008, Neufahrn / Deutschland

[3] Spanner Re^2 GmbH (Hrsg.): Bedienungsanleitung Partikelabscheider Spanner-Feinstaub-Filter, 2008, Neufahrn / Deutschland

[4] Obernberger, I.; Mandl, C.: Survey on the present state of particle precipitation devices for residential biomass combustion with a nominal capacity up to 50 kW in IEA Bioenergy Task 32 member countries, IEA Task 32 report, Graz, 2011

Schräder Al-Top		
Company	Schräder Abgastechnologie, Hemsack 11-13 D-59174 Kamen www.schraeder.com	
Type	Al-Top	
Range of performance	15 - 150 kW_N	
Fuels	• Wood pellets • Straw pellets • Energy crops	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• approx 3,000 € (applications up to 50 kW)	
Basic technological data	• electrostatic precipitator with metal filter bed • particles are precipitated within metal filter bed • filter bed is cleaned periodically by means of water spray	
Field of application	• pellet and wood chip boilers 15 – 150 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• > 80% • approx. 50%	

References

[1] Schräder Abgastechnologie GmbH (Hrsg.): Prospekt Partikelabscheider Spanner-Feinstaub-Filter, 2008, Neufahrn / Deutschland

[2] Obernberger, I.; Mandl, C.: Survey on the present state of particle precipitation devices for residential biomass combustion with a nominal capacity up to 50 kW in IEA Bioenergy Task 32 member countries, IEA Task 32 report, Graz, 2011

Technology descriptions of dust precipitator technologies using centrifugal forces

Bioflamm® MK		
Company	WVT – Wirtschaftliche Verbrennungs-Technik GmbH, Banhofstr. 55-59 D-51491 Overath-Untereschbach www.bioflamm.de	
Type	multi-cyclone separator	
Range of performance	50 – 5000 kW	
Fuels	• wood pellets • wood logs • wood chips • Straw • Cereals	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• up to 8,000 € (depending on the nominal heat output of the boiler)	
Basic technological data	• precipitation of coarse particles before electrostatic precipitators and filtration systems • axial flue gas inlet into precipitator • rotationally symmetrical construction leads to a precipitation of the particles due to centrifugal forces • dust is removed automatically into ash box • manual dust removal and maintenance	
Field of application	• automatic biomass boilers 50 – 5000 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• dust concentrations < 100 - 150 mg/m^3 • dust concentrations < 100 - 150 mg/m^3	

References

[1] WVT-Staubabscheider
http://www.bioflamm.de/downloads/Prospekt%20Staubabscheider.pdf, 09.01.2012

[2] Biedenkopf, Thomas (WVT GmbH); personal communication, 06.11.2008

Bioflamm® R		
Company	WVT – Wirtschaftliche Verbrennungs-Technik GmbH, Banhofstr. 55-59 D-51491 Overath-Untereschbach www.bioflamm.de	
Type	Rotary dust precipitator	
Range of performance	30 – 400 kW	
Fuels	• wood pellets • wood logs • wood chips • Straw • Cereals	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• up to 2,500 € (depending on the nominal heat output of the boiler)	
Basic technological data	• precipitation of coarse particles before electrostatic precipitators and filtration systems • axial flue gas inlet into precipitator with spiral casing • flue gas is forced to a rotary motion due to a routing device • dust is removed automatically into ash box • flue gas temperature < 210° C • manual dust removal and mainenance	
Field of application	• manual and automatic biomass boilers 30 – 400 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• dust concentrations < 100 - 150 mg/m^3 • dust concentrations < 100 - 150 mg/m^3	

References

[1] WVT-Staubabscheider
http://www.bioflamm.de/downloads/Prospekt%20Staubabscheider.pdf, 09.01.2012

[2] Biedenkopf, Thomas (WVT GmbH); personal communication, 06.11.2008

Technology descriptions of dust filtration technologies

KÖB KRT		
Company	Köb Holzheizsysteme GmbH Flotzbachstraße 33 A-6922 Wolfurt www.kob.cc	
Type	KRT dust filtration system	
Range of performance	up to 540 kW	
Fuels	• wood pellets • wood chips • wood dust • ash rich woody biomass fuels	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• approx. 24,000 € (F220: 60 kW – 200 kW) • approx. 26,500 € (F300: 80 kW – 270 kW) • approx. 32,000 € (F400: 100 kW – 360 kW)	
Basic technological data	• modular design with four metal filter cartridges per modul • electronic connection of 400 V is required • cleaning procedure during operation with pressurised air according to counter flow principle • ash is removed automatically into ash box	
Field of application	• KÖB "PYROT" automatic biomass boiler 100 - 540 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• > 95% • No specification available	

References

[1] WVT-Staubabscheider
http://www.bioflamm.de/downloads/Prospekt%20Staubabscheider.pdf, 09.01.2012

[2] Holzheizungen und Feinstaubemissionen Entstehungsprozesse und Lösungen
http://www.energieinstitut.at/HP/Upload/Dateien/Praesentation_Koeb_Siegfried.pdf
02.11.2008

[3] Metallgewebefilter für automatische Holzfeuerungen von 100 kW – 540 kW
http://www.holzenergie-symposium.ch/Dokumente/Referate10/15%20Scheibler%20Metallfilter.pdf 02.11.2008

Bioflamm® MF		
Company	WVT – Wirtschaftliche Verbrennungs-Technik GmbH, Banhofstr. 55-59 D-51491 Overath-Untereschbach www.bioflamm.de	
Type	MF dust filtration system	
Range of performance	30 – 2000 kW	
Fuels	• wood pellets • wood chips • others	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• up to 25,000 € (depending on the nominal heat output of the boiler)	
Basic technological data	• metal filter cartridges for precipitation • cleaning procedure during operation with pressurised air according to counter flow principle • ash is removed automatically into ash box	
Field of application	• automatic biomass boilers 50 – 5000 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• < 30 mg/m^3 • No specification available	

References

[1] WVT-Staubabscheider
http://www.bioflamm.de/downloads/Prospekt%20Staubabscheider.pdf 09.01.2012

[2] Biedenkopf, Thomas (WVT GmbH); personal communication, 06.11.2008

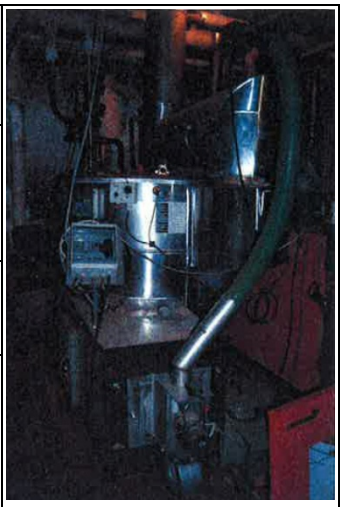
Technology descriptions of flue gas condensation technologies

Öko-Carbonizer		
Company	Bschor GmbH, An der Kohlplatte 7 D-89420 Höchstädt www.carbonizer.de	
Type	Flue gas condensation system	
Range of performance	25 – 400 kW	
Fuels	• wood pellets • wood chips • Straw and Miscanthus pellets	
Market availability	• yes	
Investment costs (incl. 19 % VAT)	• approx. 1,200 € (for 35 kW unit)	
Basic technological data	• condensing heat exchanger • consists of carbon block acting as a heat exchanger • cooling of flue gas and condensation, dust particles are trapped in condensate • particle precipitation depends on condensation rate in the flue gas	
Field of application	• automatic biomass boilers 25 – 400 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• approx. 20 % by operating with wood chip boilers • approx. 10 % by operating with multi fuel boilers	

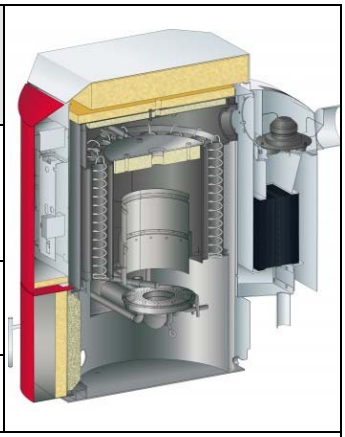
References

[1] WVT-Staubabscheider
http://www.bioflamm.de/downloads/Prospekt%20Staubabscheider.pdf 09.01.2012

[2] Obernberger, I.; Mandl, C.: Survey on the present state of particle precipitation devices for residential biomass combustion with a nominal capacity up to 50 kW in IEA Bioenergy Task 32 member countries, IEA Task 32 report, Graz, 2011

SPRAY-C		
Company	Oland Heat Tech. Norra Munsalavägen 147 FI – 66 950 Musala Tel. +358 676 41192	
Type	Recuperation of heat and impurities from flue gases	
Range of performance	25 – 100+ kW_{ht}	
Fuels	• Wood pellets, chips • Straw pellets • Energy crops	
Market availability	• Yes (also Ariterm Oy manufacturing to their applications)	
Investment costs (incl. 23 % VAT)	• Approx. 8000 € (100 kW)	
Basic technological data	• condenser unit with spray nozzles • filters, circulation pump • heat exchanger	
Field of application	• woodpellet and wood chips, boilers 25 – 100 kW	
Separation efficiency by using woody biomass by using non-woody biomass	• Small particlas <15 mg/N-m^3 • fuel saving 10 – 15 %	

References

Pellematic Plus		
Company	ÖkoFEN Forschungs- und EntwicklungsgesmbH Gewerbepark 1 A-4133 Niederkappel	
Type	Integrated flue gas condensation system	
Range of performance	12 – 32 kW	
Fuels	• wood pellets	
Market availability	• yes	
Investment costs (incl. 20 % VAT)	• approx. 1,200 € (for flue gas condensation unit)	
Basic technological data	• automatic wood pellet boiler with integrated flue gas condensation system which consists of carbon block acting as a heat exchanger • cooling of flue gas and condensation, dust particles are trapped in condensate • particle precipitation depends on condensation rate in the flue gas	
Field of application	• only available with Ökofen Pellematic plus wood pellet boiler	
Separation efficiency by using woody biomass by using non-woody biomass	• approx. 40 % according to manufacturer information, > 10 % according to test measurements of Austrian Bioenergy Centre • No specification available	

References

[1] www.pelletsheizung.at

[2] Obernberger, I.; Mandl, C.: Survey on the present state of particle precipitation devices for residential biomass combustion with a nominal capacity up to 50 kW in IEA Bioenergy Task 32 member countries, IEA Task 32 report, Graz, 2011

7.4.3 Industrial scale applications

Emission reduction measures particularly for the removal of particles, NO_x and SO_2 are state of the art for industrial combustion systems. Other components that can also be reduced by secondary measures are HCl, heavy metals and PCDD/F. However, secondary emission reduction measures for these components will not be presented in detail because the solutions are made individually for each plant. Furthermore, information and data about construction, operation and characteristics of the mentioned secondary measures are scarcely available.

7.4.4 Heat supply costs

Within the MixBioPells project the heat supply costs have been calculated for selected case studies. More detailed information can be found in the Cost Analysis Report /52/ of the project. The following cost categories have been taken into account, Table 35.

Table 35: Cost categories included in the calculation of the heat supply costs

Investment costs	• boiler • storage room • construction and initial operation • flue gas treatment system • heating grid
Running costs	• fuel costs • auxiliary energy costs • filling flat rate • chimney sweeper costs • maintenance and repair

The investment costs of heating systems for alternative biomass are in general higher than for comparable fossil fuelled heating systems. However, fuel costs as a major part of the annual running costs have a wide influence on the heat supply costs and thus on the economics of heating systems (Figure 18). Due to the increased impact of fuel costs, medium to large scale heating systems which are operated with alternative pellets are more likely to be profitable than fossil fuel systems. Thus, heating systems operated with alternative and mixed biomass pellets or briquettes are getting favourable after an operation time well below the middle of the service life. For small scale profitability within the service life can only be achieved for a particularly high difference between fossil fuel price and alternative and mixed biomass pellet price.

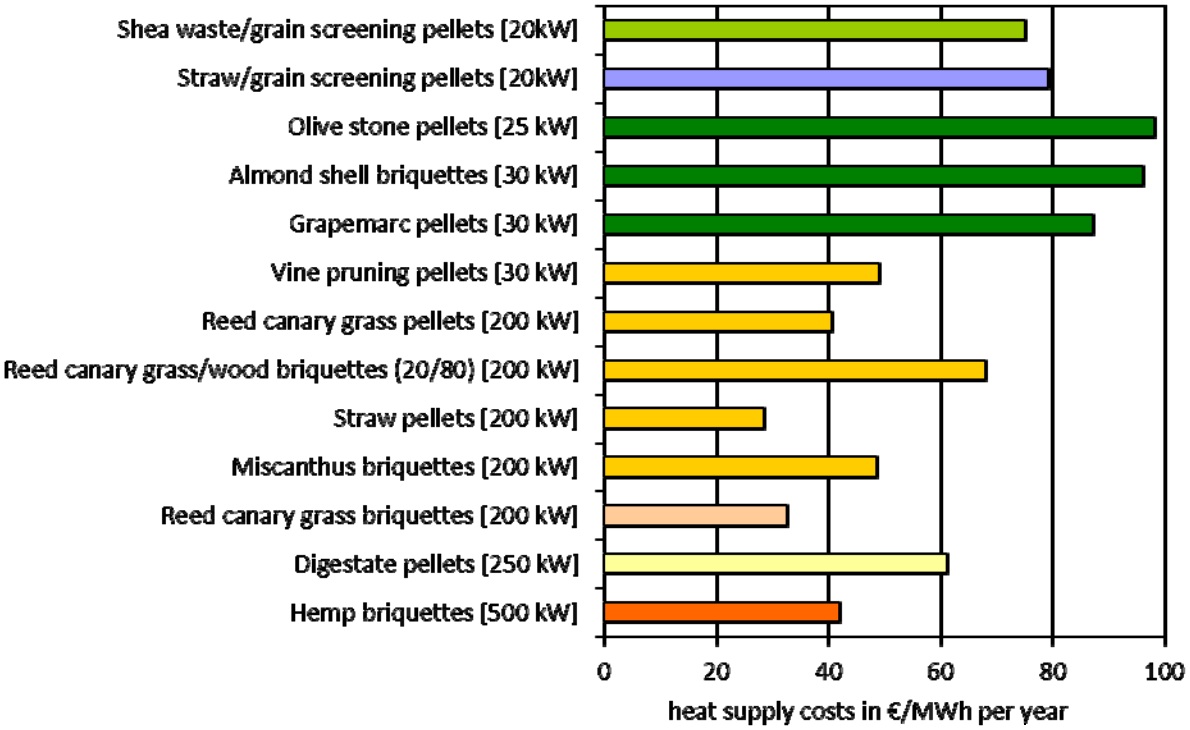


Figure 18: Comparison of heat supply costs of the alternative combustion systems of the case studies in €/MWh per year /52/

8 ANNEX

A: List of previous and ongoing projects

- Machbarkeitsstudie über die Brikettierung und die thermische Nutzung von Landschaftspflegeheu in einer Kleinfeuerungsanlage (Feasability study about briquetting and thermal utilisation of hay in small scale combustion units regional), 2008, Austria
- BEStII - Landwirtschaftliche Brennstoffe für Kleinfeuerungsanlagen (BEStII - Agricultural biofuels for small-scale combustion units), FFG (Kplus-Program), Austria
- Technologie Portrait feste Biomasse (Solid Biomass a technology portrait), Energiesysteme der Zukunft, 2000, Austria
- Pelletsbrenner der Zukunft (Pellets combustion technology for the future), FFG (Kplus-Program), 2009, Austria
- Pelletierung von Obstkernen (Pelletising of fruit stones), 2006, Austria
- Pelletierung und Verbrennung von Landschaftspflegeheu (Pelletising and combustion of hay from landscape gardening), 2007, Austria
- Pelletizing experiments with shavings of Bangkirai, Teak and Merbau, 2007, Austria
- Pelletierung von Luzerneheu und Apfeltrester für Kleintierfütterung (Pelletising of lucern hay and apple pomace), 2007, Austria
- Peat pellets as a source of heat energy in Finland, 2004, Finland
- Fuels for CO_2 reduction in power plants, 2005, Denmark
- Straw and wood pellets applicability in small scale appliances, 1994, Denmark
- The use of alternative biomass in small scale boilers from 20kW to 250 kW, 1999, Denmark
- Quality characteristics of Biofuel Pellets, 2002, Denmark
- Options for Achieving the Target of 45MTOE from energy cropping in the EU in 2010, 2003, Denmark
- Utilization of Ash fractions from Alternative Biofuels used in Power Plants, 2008, Denmark
- Förutsättningar för användning av rörflensbriketter och hackad rörflen i mindre värmecentraler (The conditions for use of reed canary grass briquettes), 2010, Sweden
- Syntes av Energimyndighetens program ”Uthållig tillförsel och förädling av biobränsle” delen Bränsleförädling och Jordbruksbränslen, etapp 1 (Synthesis of the Energy Agencies programme "Sustained delivery and processing of biomass" component Fuel Processing and Agriculture Fuels, Phase 1), 2010, Sweden
- Miscanthuspellets als Alternativbrennstoff: Chancen, Erfahrungen und Probleme (Miscanthuspellets as alternative fuel: opportunities, experiences and problems), 2010, Germany
- Strohpellets für Kleinfeuerungsanlagen (Straw pellets for small-scale combustion units), 2008, Austria

- Nutzungsalternativen von Grünlandaufwüchsen in sächsischen Vorgebirgslagen –Ein Beitrag zur Erhaltung der Kulturlandschaft und des ländlichen Raums (Possibilities for the energetic utilization of residues from grassland), 2007, Germany
- Energiekornmonitoring - Erforschung der technischen und wirtschaftlichen Möglichkeiten für die thermische Nutzung von Energiekorn und Strohpellets in Kleinfeuerungsanlagen im Praxisbetrieb (Investigation of technical and economic possibilities for thermal utilisation of energy grain and straw pellets in small scale combustion units (practical experiences)), 2006, Austria
- Småskalig brikettering av hampa – förstudie (Small-scale briquetting of hemp - feasibility study), 2006, Sweden
- Upgraded Biofuels - Effects of Quality on Processing, Handling Characteristics, Combustion and Ash melting, 2004, Sweden
- Entwicklung einer wirtschaftlichen Prozesskette zur energetischen Nutzung von halmgut- und holzartiger Biomasse im Freistaat Sachsen (Development of an economic process chain for the energetic use of stalks and woody biomass in the Free State of Saxony), 2002, Germany
- Verbrennungsversuche mit naturbelassenen biogenen Festbrennstoffen in einer Kleinfeuerungsanlage -Emissionen und Aschequalität (Combustion tests with natural biogenic solid fuels in small scale system - Emissions and ash quality), 2000, Germany
- BMU Havelland -Entwicklung von übertragbaren Konzepten zur Nutzung von halmgutartigen Landschaftspflegematerialien (Grassland energy Havelland – concept development for the utilization of hay from the landscape conservation), 2012, Germany
- Verbundvorhaben "Biobrennstoffdesign - Brennstoffauswahl und Mischbrennstoffbildung beim Brennstoffdesign" (Solid Biofuels Design: Basic studies on the energetic use of alternative mixed biomass pellets), 2011, Germany
- Verbundprojekt: C4-Kompakt "Entwicklung einer optimierten Produktionskette für die Bereitstellung von Miscanthus-Mischpellets zur Nutzung in Biomassefeuerungsanlagen" (Collaborative Project: C4-Compact "To develop an optimized production chain for the provision of Miscanthus-mixed pellets for use in biomass combustion plants"), 2013, Germany
- Eignung und Optimierung von Halmgutpresslingen für kleine und mittlere Feuerungsanlagen (Suitability and optimisation of strawpellets for small and medium sized combustion plants), 2012, Germany
- Syntes av Värmeforsks forskningsprogram ”Grödor från åker till energi” (Synthesis of Värmeforsks´ research programme ”Crops from field to energy”), 2009, Sweden
- Biobränsle från det jämtländska jordbruket – en studie om jordbrukarnas alternativkostnad vid odling av rörflen (Biofuel from the agriculture in Jämtland - A study of the farmers opportunity cost when cultivating reed canary grass), 2008, Sweden
- 2-jähriges Monitoring einer Kleinfeuerungsanlage für die thermische Nutzung von Landschaftspflegeheu (2-year monitoring of a small scale combustion unit fired with hay), 2010, Austria
- Energiebiomasse aus Niedermooren (Biomass from fens), 2009, Germany

- BIOENERGIS - GIS-based decision support system aimed at a sustainable energetic exploitation of biomass at regional level (BIOENERGIS - GIS-based decision support system aimed at a sustainable energetic exploitation of biomass at regional level), 2011, Austria
- Energiproduktion från rörflen Handbok för el- och värmeproduktion (Energy production from Reed canary grass A handbook for electricity and heat production), 2008, Sweden
- Getreidekörner als Brennstoff für Kleinfeuerungen - Technische Möglichkeiten und Umwelteffekte (Cereal grains as a fuel for small furnances - Technical possibilities and environmental effects), 2007, Germany
- Energetische Verwertung von Getreide und Halmgutpellets (Energy recovery by cereals and straw pellets), 2006, Germany

B: Key actors lists

B1 List of raw material suppliers

Company / Farm	Address	Website	Raw materials
Austria			
Joesef Wiesinger	Rannersdorf 24	Not available	Straw
Alfred jun. Hammer	Hauptstr 65 A-2185 Prinzendorf an der Zaya	Not available	Straw
Karl Stadler	Hauptstr.76 A-2185 Prinzendorf an der Zaya	Not available	Straw
Andreas Glück/ Gernot Glück	Sommerseite 44 A-2225 Loidesthal	Not available	Straw
Agrarenergie Weinviertel	Bahnstrasse 32 A-2130 Mistelbach	http://www.agrar-energie.at/	Miscanthus
Richard Prossenitsch	Zwerndorf 55 A-2295 Oberweiden	Not available	Miscanthus
Georg Maier	Landwirt, Kammerrat Hauptstraße 20 A-2261 Angern an der March	Not available	Miscanthus
Leo Strobl	Oberort 78 A-2130 Eibesthal	Not available	Miscanthus
Hannes Stelzhammer	Grub 4 3071 Böheimkirchen	http://www.miscanthus-giganteus.at	Miscanthus cultivation
Spain			
COVAERSA	Cuesta Las Piedras s/n 03330 Crevillent España	Not available	Almond shells
IDENAYR	Polígono San Miguel C/ Isaac Newton, 5 5830 Villanueva de Gállego (Zaragoza).	Not available	Miscanthus
COTEVISA	Finca San Mario, Ctra. Nacional 340, Km. Ciudad: L`Alcudia Provincia: Valencia Código Postal: 46250	www.cotevisa.com	Paulownia
Finland			
Vapo Oy	Yrjönkatu 42, PL 22, FI-40100 Jyväskylä	www.vapo.fi	Wood, peat, reed canary grass
Vesa Ritola	Tampereentie 300, FI-61680 Mantila	Not available	Straw
Tuomo Säntti	Erkkilänmäentie 47 FI-61720 Koskue	Not available	Straw
Simo Sillanpää	FI_42700 Keuruu	Not available	Reed canary grass

Company / Farm	Address	Website	Raw materials
Germany			
Maschinenring Trier-Wittlich e. V.	Maschinen- und Betriebshilfsring Trier-Wittlich e.V, Europa-Allee 5, 54343 Föhren	www.mr-trier-wittlich.de	Miscanthus, grape marc, vine pruning, straw, residues from landscape gardening
Maschinenring Schwalm-Eder e.V.	Maschinenring Schwalm-Eder e.V., Schulstraße 17, 34590 Wabern-Zennern	www.mr-schwalm-eder.de	Sewage sludge, wood, plant residues, compost
MR Schleswig-Holstein Energie Pool GmbH & Co. KG	MR Schleswig-Holstein Energie Pool GmbH & Co. KG, Dorfstraße 14a, D 24819 Nienborstel	www.mep-sh.de	Wood, Straw, cereals, digestates, rape press cake, spelt husks
Maschinenring und Betriebshilfdienst Ortenau e.V.	Maschinenring und Betriebshilfdienst Ortenau e.V. Bahnhofstraße 67 77731 Willstätt-Legelshurst	www.mr-ortenau.de	Wood, Rape press cake, residues from landscape gardening
Wetterauer Agrar Service GmbH	Wetterauer Agrar Service GmbH Kölner Straße 10 61200 Wölfersheim	www.rapsbiodiesel.de	Wood, straw, rape press cake, residues from landscape gardening
MR Hessen GmbH	MR Hessen GmbH, Brunnenstraße 10, 34516 Vöhl-Basdorf	www.mr-hessen.de	Wood, Miscanthus
Envitec Biogas AG	Boschstraße 2, 48369 Saerbeck Email: info@envitec-biogas.de	www.envitec-biogas.de	Digestates
Denmark			
Hjaltelin Agro	Caspar Müllers Gade 32 6000 Kolding	www.hjaltelin.dk/	Trader of pellets and various alternative biomass fuels
AKS	Tøndervej 3 6520 Toftlund	www.a-k-s.dk/	Producer of starch from potato.
Verdo	Agerskellet 7 8920 Randers NV	www.verdo.dk	Pellet producer, trader of pellets and various alternative biomass fuel
Nordic Sugar	Langebrogade 1 1014 København K	www.nordicsugar.com	Sugar beet residues
AarhusKarlshamn	"M.P. Bruuns Gade 27 8000 Aarhus C	www.aak.com	Food ingredients producer with biomass residues
Inbicon	Kraftværksvej 53 000 Fredericia	www.inbicon.dk	Ethanol on Wheat straw
CP Celco	Ved Banen 16 4623 Lille Skensved	www.cpkelco.com	Food ingredients producer with biomass residues
Carlsberg	Vestre Ringvej 111 7000 Fredericia	www.carlsberg.dk/	Brewery Mesh

Company / Farm	Address	Website	Raw materials
Denmark			
Unibrew	Tværgade 2 DK-5000 Odense C	www.royalunibrew.com	Brewery Mesh
Emmelev Mølle	Emmelevgyden 25 5450 Otterup	www.emmelev.dk/	Rape cakes
Egeskov oliemølle	Egeskov 5772 Kværndrup	www.egeskov-slot.dk/da/intro	Rape cakes
Hjaltelin Agro	Caspar Müllers Gade 32 6000 Kolding	www.hjaltelin.dk/	Trader of pellets and various alternative biomass fuels
Italy			
ISPARO	Roberto Capoferri Via Enrico Mattei IT-25040 Corte Franca (BS)	www.cascinaclarabella.it/pagina.aspx?id=102	Grape marc and olive press cake
Grandi Molini Italiani SpA	Sandro Zanirato Via dell'Elettricità 13 IT-30175 Porto Marghera (Venezia)	Not available	Bran grains
CAC	Edmo Tersi Via Calcinaro 1450 IT-47522 Martorano - Cesena (FC)	Not available	Agricultural residues from farms
Rinnova Green Energy srl	Alberto Bergonzi Via Rottaiole 3 IT-26040 Scandolara Ravara (CR)	www.r-innova.it/	Wood chip producer
Demetra	Zaninelli Cristian Via Villa di Sotto, 57/B 25046 Cazzago S.M. (BS)	Not available	Residues from viniculture
Sweden			
Låttra gård	Göran Winkler Låttra Gård , 64393 VINGÅKER	www.lattrabriketten.com/index1.html	Reed Canary Grass
Stocktorps gård	Mait Dumky Stocktorpsgård 64292 FLEN	http://stocktorpsgard.se/	Straw

B2 Pelletising and briquetting technology suppliers

Company	Address	Website	S	M	L	Raw material	PP	BP
GERMANY								
Amandus Kahl GmbH & Co. KG	Dieselstraße 5 21465 Reinbek	www.akahl.de	1	3	5	saw dust, straw	x	-
MÜNCH-Edelstahl GmbH	Weststraße 26 40721 Hilden	www.muench-gmbh.de	-	3	1	saw dust, straw	x	-
Pusch AG	Auf der Weid 1-15 56242 Marienrachdorf	www.pusch.ag	-	1	1	straw, wood	x	-
Salmatec	Bahnhofstraße 15A 21376 Salzhausen	www.salmatec.de	n.a.			straw, horse dung, greens	x	-
Jumbo Group	Feldbach 25 86647 Buttenwiesen	www.jumbo-group.de	1	-	-	straw	x	-
EcowroXX	Kreuzkrug 44 31604 Raddestorf	www.ecowor xx.de	1	-	-	wood, straw, hay, Miscanthus	x	-
Bauer Power	Brunnenstraße 13 65428 Rüsselsheim	www.energievomland.de	-	1	-	straw, hay, Miscanthus	x	-
Michael Schmitt	Treppenstrasse 1 66740 Saarlouis	www.schmitt-energie.de	5	1	-	straw, sunflower, spelt	x	-
RUF Maschinenbau GmbH & Co. KG	Hausener Str. 101 86874 Zaisertshofen	www.briketieren.de	5	3	-	straw, all kinds of fiber materials	-	x
Maschinen-fabrik Köppern GmbH &Co. KG	Königsteiner Str. 2 45529, Hattingen	www.koeppern.de	n.a.			n.a.	-	x
Votecs	Olgastraße 13 74072 Heilbronn	www.votecs.de	n.a.			wood shavings, hay	-	x
ADELMANN Umwelt GmbH	Johann-Schöner-Str.73 97753 Karlstadt	www.adelmann.de	n.a.			straw, wood, Miscanthus	-	x
Wessel GmbH Kessel- und Apparatebau	Hagdornstraße 10 46509 Xanten	www.wessel-xanten.de	n.a.			wood	x	-

S… Small <500 kg/h; M… Medium 500-2000 kg/h; L… Large >2000 kg/h; PP… Pellet press; BP… Briquette press; n.a. … not available

Company	Address	Website	S	M	L	Raw material	PP	BP
GERMANY								
EUROPRESS	von-Arenberg Str.1 49762 Lathen	www.europress-lathen.com	1	-	-	saw dust	-	x
FUCHS-ALMABOIS	Hauptstraße 199 79576 Weil am Rhein	www.fuchs-almabois.com	1	-	-	wood	-	x
GHEbavaria Maschinen GmbH	Gebr.-Hofmann-Ring 4 97246 Eibelstadt	www.ghebavaria.de	n.a.			wood	-	x
Gross Apparatebau GmbH	Salzstraße 96-98 74076 Heilbronn	www.gross-zerkleinerer.de	3	-	-	saw dust, hay	-	x
Höcker Polytechnik GmbH	Borgloher Straße 49176 Hilter	www.hoecker-polytechnik.de	3	-	-	cellulosic material	-	x
Nestro-Lufttechnik GmbH	Odenwaldring 9 63934 Röllbach	www.nestro.de	4	-	-	wood, paper	X	x
Reinbold Entsorgungs-technik GmbH	Gottlieb-Daimler-Straße 13 75050 Gemmingen,	www.reinbold.de	8	-	-	saw dust	-	x
Schuko GmbH	Gewerbepark 2 49196 Bad Laer,	www.schuko.de	6	-	-	saw dust, paper dust	-	x
SPÄNEX GmbH	Otto-Brenner-Straße 6 37170 Uslar	www.spaenex.de	10	-	-	wood, paper, biomass	-	x
TH-Alternativ-Energie	Rothelebuch 3 87637 Seeg/Allgäu	www.th-alternativ-energie.de	1	-	-	wood, straw, hay, Miscanthus	-	x
Weimar Maschinenbau GmbH	Gewerbegebiet Bustadt 74360 Ilsfeld	www.weima.com	n.a.			wood, other biomass	-	x
WINKEL Lufttechnik GmbH	Friedhofstraße 54317 Osburg	www.jkf-industrie.de	4	-	-	wood, other biomass	-	x
AGRIFA GmbH	Oldenburger Straße 107 26316 Varel	www.agrifa.eu	5	-	-	wood, straw etc.	-	x
AUSTRIA								
ANDRITZ AG	Stattegger Strasse 18 8045 Graz	www.andritz.com	1	1	1	n.a.	x	-

S… Small <500 kg/h; M… Medium 500-2000 kg/h; L… Large >2000 kg/h; PP… Pellet press; BP… Briquette press; n.a. … not available

Company	Address	Website	S	M	L	Raw material	PP	BP
AUSTRIA								
Albert Knoblinger GmbH & Co. KG	Oberbrunnerweg 10 4910 Ried im Innkreis	www.knoblinger.at	-	-	1	wood	x	-
Bühler AG	Niederlassung Oesterreich Münchner Bundesstrasse 142	www.buhlergroup.com			3	wood, oil press residues and cereals	x	
NEUHAUSER Fürlinger GmbH	Fasanenweg 4 4616 Weisskirchen	www.neuhauser-pelletstechnik.at	2	3	1	wood	x	-
Brikettier-technik Siegel	Lastenstraße 7 9560 Feldkirchen	www.siegel-mb.at	6	-	-	wood	-	x
Wieder-Maschinenbau GmbH	Steindorf, Gewerbegebiet Süd 7, 5204 Straßwalchen	www.wieder-maschinenbau.at	2	-	-	wood,	-	x
ITALY								
General Dies srl	Marialuisa Meneghello Via Strà 182 37030 Colognola ai Colli	www.generaldies.com	3	5	1	wood, straw, hay, other biomass	x	-
Nova Pellet	Via Brescia,56 - Pontevico	www.generaldies.com	2	1	1	wood	x	-
MakXilia s.r.l.	Via Lungofino 187 - Centro Comm.le Ibisco, Blocco B/1 - Citta' Sant'Angelo (PE)	www.novapellet.it	3	1		wood, cereals, chicken litter	-	x
O.M.A impianti	Via Ponticelli, 51 - Pieve a Nievole (Pistoia)	www.MakXilia.it	3			wood	-	x
Henergeia Helios	Chislaz (Romania)	www.oma-srl.com	2	2	1	wood and agricultural residues	x	-
Larus Impianti s.r.l.	Via dei Cascinotti 7 - Credera (CR)	www.henergeiahelios.com	1	1		wood and agricultural residue	X	-
MTD srl	Via Volta, 2 - Settimo di Pescantina (Ve)	www.pellet.it	n.a.			wood	X	-
ASCOT	Via dell'Industria 38 - Marano Vicentino	www.mtdsrl.it	6			cellulistic material	x	-
BS Bollareto impianti	Via dell'Industria 16/14 - PORTO MANTOVANO	www.ascot-matic.com	12	2		dry and wet biomass	x	x

S… Small <500 kg/h; M… Medium 500-2000 kg/h; L… Large >2000 kg/h; PP… Pellet press; BP… Briquette press
n.a. … not available

Company	Address	Website	S	M	L	Raw material	PP	BP
ITALY								
Costruzioni Nazzareno	Via delle Industrie, 17 - Vacil di Breda di Piave (TV)		5	1		wood	x	x
Kemyx	Corso Matteotti, 200 - Montecatini Terme (PT)		n.a.			wood and agricultural residue	x	-
La meccanica di Reffo	via Nicolini,1 – Loc. Facca 35013 – Cittadella (PD)	www.la meccanica.it	1	1	2	wood	x	-
CO.MA.FER	Via de Gasperi, 25060 Collebeato Brescia	www.coma fer.it	7				x	x
DI PIÙ	Via dellÌnnovazione, 11, 36042 Breganze	www.di-piu.com	4	7	3	wood, biomass residues	-	x
SWEDEN								
Biopress	Kånnavägen 3B 34131 Ljungby		2	1		wood	x	-
Bogma	Box 71 523 22 Ulricehamn	www.bogma.com	6	2		wood, straw, grass	-	x
SPC	Skaraborgsvägen 35E 50630 Borås		3	2		wood, straw, grass	x	-
FINLAND								
Aimo kortteen Konepaja Oy	Pohjolantie 2 84101 Ylivieska	www.murska.fi	1	-	-	wood, other biomass	x	-
DENMARK								
Andritz Feed & Biofuel	Glentevej 5-7, 6705 Esbjerg Ø	www.andritz.com	n.a.			Wood, straw, miscanthus	x	
C.F. Nielsen a/s	Solbjergvej 19, 9574 Baelum	www.cf nielsen.com	2	3	1	wood, straw		x
SPAIN: No manufacturers of pelletizing equipment could be investigated.								

S… Small <500 kg/h; M… Medium 500-2000 kg/h; L… Large >2000 kg/h; PP… Pellet press; BP… Briquette press; n.a. … not available

B3 Fuel suppliers and producers

Company	Address	Website	Raw materials	Capacity (t/a)		
				S	M	L
GERMANY						
Pusch AG	Auf der Weid 1-15 56242 Marien-rachdorf	www.agrarstick.de	wood, straw, hay, Miscanthus, digestates, grape marc and mixtures	-	x	-
ABW UG Apoldaer Biomassewerk	Sulzaer Str. 96 99510 Apolda	Not available	Wood, straw, rape press cake, soy bean press cake, hay, Miscanthus, additives and mixtures	-	x	-
Kaliro GbR	Hengemühlweg 204 48432 Rheine	www.kaliro.de	Straw, wood	-	x	-
Lange & Meyer GbR	Wechold 33 27318 Hilger-missen	www.strohpellets.de	Straw	-	x	-
Agrarhandel B+B Müller	Dietinger-strasse 31 78661 Dietingen-Böhringen	www.agrarhandel-mueller.de	Straw, hay	x	-	-
BauerPower	Brunnenstraße 13 65428 Rüssels-heim-Bauschheim	www.energievom land.de	Straw, digestate, Miscanthus	x	-	-
Futtermittel- und Dienstleistungs GmbH Sonnewalde	Sonnewalder Str. 03249 Goßmar	www.futtermittel-gmbh.de	Straw, additives pellets	-	-	x
Nawaros-Hof Herrmann GmbH	Würzburger Straße 82 97854 Steinfeld	www.nawaros-hof.de	Straw, hay	-	x	-
PLANTAQENZ AG	Lübecker Str. 15 23623 Ahrensbök	www.plantaqenz.de	Straw, digestate, horse manure pellets	-	x	-
AV Handels GmbH	Lohwiesenweg 1 73527 Schwäbisch Gmünd	www.av-biobrennstoffe.de	Wood, straw pellets and briquettes	-	x	-

S… Small < 5,000 t/a; M… Medium < 20,000 t/a; L… Large >20,000 t/a

Company	Address	Website	Raw materials	Capacity (t/a)		
				S	M	L
FINLAND						
Vapo Oy	Yrjönkatu 42, 40100 Jyväskylä	www.vapo.fi	Wood and peat	-	-	x
Biobotnia Oy	Ilveksentie 136, 61760 ILVESJOKI	www.biobotnia.fi	Alternative and mixed biomass	x	-	-
Jalasjärven Lämpö Oy	Lähdetie 2, 61600 JALASJÄRVI	Not available	Wood and straw	x	-	-
PRM-Briketöinti Oy	Reisjärventie 2330 44800 Muurasjärvi	Not available	Alternative and mixed biomass, wood	x	-	-
Leijonapelletti Oy	Vastustie YTJ 31300 TAMMELA	Not available	Alternative and mixed biomass, wood	-	x	-
DENMARK						
Vattenfall A/S	Støberigade 14, 2450 København	www.vattenfall.dk	Straw and wood	-	-	x
DLG	Axelborg Vesterbrogade 4 A 1620 København V	www.dlg.dk	Alternative biomasses	-	-	x
Hjaltelin Agro	Caspar Müllers Gade 32 6000 Kolding	www.hjaltelin.dk	Alternative biomasses	not available		
Verdo	Agerskellet 7 8920 Randers NV	www.verdo.dk	Wood and alternative biomasses	-	-	x
Dangrønt	Industrivej 13 870 Ølgod	www.dangroent.dk	Hay and straw	not available		
ITALY						
Roana Cereali	Via Mario Malfatto 46/a 45010 S.Apollinare	www.roanacereali.com	wood and maize	x	-	-
Produttori Sementi Verona srl	Via Strà 177 37030 Colognola ai Colli	www.produttoripellet.com	Grape marc, vine prunings	x	-	-
Italiana Pellets	Via Cascina Nuova 27050 Corana	www.italianapellets.com	wood	-	-	x
Bagioni Group	Via Serachiedsa 1/C 47122 Forlì	www.gruppobagioni.com	Herbaceous biomass, alfalfa, maize, straw	not available		

S… Small < 5,000 t/a; M… Medium < 20,000 t/a; L… Large >20,000 t/a; n.a….not available

Company	Address	Website	Raw materials	Capacity (t/a)		
				S	M	L
SWEDEN						
Bioenergi i Luleå	Uddebovägen 5 973 23 Luleå	www.bioenergi lulea.se	Wood and peat	-	-	x
Härjedalen Miljöbränsle AB	Södra Hantverks-gatan 4, 842 31 Sveg	www.hmab.se	Wood and peat	-	-	x
Glommers Miljöenergi	Storgatan 1 930 81 Glommersträsk	www.gmepellets.se	Reed canary grass, wood	x	-	-
Kastebergs Gård	Österlöv Kasteberg 2, Ljungby	www.kasteberg. com	Wood, straw	x	-	-
Skånefrö AB	Storgatan 1 272 93 Tommarp	www.skanefro.se	Agricultural restproducts, wood	x	-	-
Neova AB	Box 1143 824 13 Hudiksvall	www.neova.se	Wood and peat	-	-	x
Låttra Gård Bioprodukter	Låttra Gård 1, 643 93 Vingåker	www.lattra briketten.com	Reed canary grass	x	-	-
SPAIN						
COVAERSA ENERGÍAS	Cuesta Las Piedras 03330 Crevillent	www.briquetas briec.com	Almond shells	-	x	-
AGROFERESTAL NAVA	SL Vegalloba s/n 33520 Nava	www.agroforest alnava.es	wood	-	-	x
ENERPELLET	Larrauri 1 48160 Derio	www.enerpellet. com	wood	not available		
PELLET Asturias	Industrial Park La Curiscada 33877 Tineo	www.pellets asturias.com	wood	-	-	x
AMATEX	Polígono Industrial "La Nava" N-234. 42146. Cabrejas del Pinar SORIA	www.amatex.es	Wood, straw	-	-	x
Orientación sur SL	Av. 1º de Julio, 70 - Local 4 13300 Ciudad Real	www.orientacion sur.es	Vine pruning	-	x	-
NATURFOC	Pol. Ind. La Cava C/ Alfarrasí nº6 46892 - Montaverner	www.naturfoc.com	Wood, prunings	not available		
AUSTRIA						
FEX ÖKO-Faserverarbeitungs GmbH	Dobermanns-dorferstraße 1 2183 Neusiedl/ Zaya	www.fex.at	Straw	-	x	-
Martin Zimmermann	Bahnstrasse 32 2130 Mistelbach	www.agrar-energie.at	Miscanthus	x	-	-
ADF Miscanthus	Hausleiten 4 3321 Stephanshart	www.adf-miscanthus.at	Miscanthus	x	-	-

S… Small < 5,000 t/a; M… Medium < 20,000 t/a; L… Large >20,000 t/a

B4 List of storage system suppliers

Company	Address	Website	Storage systems
Finland			
Antti-Teollisuus Oy	Koskentie 89, FI-25340 KANUNKI	www.antti-teollisuus.fi	large silos, transport and delivery devices for pellets, mechanical separators etc.
Oy Nord Mills Ltd	Pirttisentie 224 FI-62435 PIRTTINEN	www.nordmills.fi	small silos, transport and delivery devices burners for pellets
Reikälevy Oy	Yrittäjäntie 22 FI-62375 Ylihärmä	www.reikalevy.fi	small silos, transport devices for pellets
Pelletti-imurit Vanhala Oy	Asemantie 16, FI-48720 KOTKA	www.pellettiimurit.fi	Small scale pneumatic transport system to pellets
Germany			
Mall Umwelt-systeme	Hüfinger Str. 39-45 78166 Donaueschingen	www.mall.info	Subterrean pellet storage systems (6,5-60m³)
Paradigma Deutschland GmbH	Ettlinger Str. 30 76307 Karlsbad	www.paradigma.de	Textile silos for storage of pellets up to 5.6 t
SOLARvent Biomasse-Heizsysteme GmbH	Braunschweiger Str. 10 37581 Bad Gandersheim	www.solarvent.de	Textile silos for storage of pellets up to 6.5 t, individually designed store room with slants
A.B.S. Silo- und Förderanlagen GmbH	Industriepark 100 74706 Osterburken	www.abs-silos.de	Textile silos up to 50 m³
Allg. Silotec	Rodbachstraße 24 74397 Pfaffenhofen	www.allg-silotec.de	Textile silos
C. Tiek GmbH	Am Kiesberg1,49733 Haren-Lindloh	www.tiek.de	Containers with hydraulic push floor
CASTAN GmbH - Industriebedarf		www.ca-pellets.de	Accessories for pellet storage systems
Neuero Farm- und Fördertechnik GmbH	Hermann Unbefunde Str.6 49324 Melle	www.neuero-farm.de	Storage silos up to 10,000 m³
SAXIL-WERK GmbH	Hans-Weigel-Str. 10b 04319 Leipzig	www.saxil.de	Textile silos for storage of pellets up to 7.6 t and for industrial applications
Schellinger KG	Schießplatzstr. 1–5 88250 Weingarten	www.schellinger-kg.de	Subterrean pellet storage systems, textile silos for storage of pellets up to 7 t, individually designed store room with slants
Silo+Fördertechnik Berger GmbH+Co	Bruckstraße 56, 70734 Fellbach	www.silo-berger.de	Storage silos up to 100 m³
Denmark			
BM Silofabrik	Morrevej 7, Tvis 7500 Holstebro	www.bmsilo.com	Different types of silos for indoor and outdoor location
Orla Hansen A/S	Smedesvinget 15 DK-6880 Tarm	www.orlahansen.dk	Different types of silos for indoor and outdoor location

Company	Address	Website	Storage systems
Italy			
Blu energy	Via Garibaldi, 2099 - 45030 Frassinelle Polesine - (ROVIGO) ITALIA	www.bluenergy.eu	Silos, small storage systems. Transport and delivery pellet systems
Ecojoule	Via Acqui, 25 0098 Cascine Vica Rivoli (TO)	www.ecojoule.it	Silos, small storage systems. Transport and delivery pellet systems
MEPE	Via F.lli Bandiera, 19 10042 Nichelino, Torino	www.mepesrl.it	Silos, small storage systems. Transport and delivery pellet systems
Costruzioni Nazzareno	Via delle Industrie, 17 - 31030 Vacil di Breda di Piave (TV)	www.nazzareno.it	Storage and transport systems
Olivari meccanica	Via Bembo, 47 - Coniolo (Bs)	www.olivarimeccanica.it	Silos, transport systems
Erin	via degli Artigiani, 2-4 Camisano (CR) 26010	www.erin-pellet.com	Storage and transport systems
PTM	Via M. Tognato, 10 – 35042 Este (PD)	www.p-tm.it	Storage and transport systems
AIR-TEC	Via del Cerchio 3/2 – 40012 Calderara di Reno, Bologna	www.air-tec.it	Transport systems
Sweden			
Bjurenwall	Alf Bjurenwall AB Box 55, 734 28 Kolbäck	www.bjurenwall.se	Silos and storage
Jeffrey Rader	Jeffrey Rader AB Domnarvsgatan 11 163 53 Spånga, Stockholm	www.jeffreyrader.com	Silos, storage
Mafa	MAFA i Ängelholm AB	www.mafa.se	Silos, storage
Peal	PEAL AB Garnisonsgatan 11 254 66 Helsingborg	www.peal.se/default.html	silos
Petro Ett AB	Petro ETT AB Helsingborgsvägen 33 S-262 72 Ängelholm	www.petroett.se	transportation
Spain			
Supersilo	C/Hornos Altos s/n 33930 Langreo	www.supersilo.es	All types of pellets

Company	Address	Website	Storage systems
Austria			
Hargassner GesmbH	Anton Hargassnerstr.1 A-4952 Weng	www.hargassner.at	Heating container with integrated storage room, storage filling system
Windhager Zentralheizung GmbH	Anton-Windhager-Str. 20, A-5201 Seekirchen	www.windhager.com	Advice for storage rooms, sheet steel tanks, fabric tanks, buried tanks
ÖkoFEN Forschungs- und Entwicklungs Ges.m.b.H.	Gewerbepark 1, 4133 Niederkappel	www.pelletsheizung.at	Advice for storage rooms, storage tanks, fabric tanks ,delivery systems from storage to the burner
Gustav Petri & Co. Stahlservice und – Betriebs-Ges.m.b.H	Lamezanstrasse 12, A-1230 Wien	www.petristahl.at	Different delivery systems, different storage tanks, advice for storage rooms

B5 Manufacturers of combustion technologies

Name	Address	Contact details
AUSTRIA		
ETA Heiztechnik GmbH	Gewerbepark 1 4716 Hofkirchen an der Trattnach	Tel.: +43 (0)7734 2288-0 Fax: +43 (0)7734 2288-22 info@eta.co.at
Fröling	Industriestraße 12 4710 Grieskirchen	Tel. +43 7248 / 606 - 0 Fax:+43 7248 / 606 - 600 info@froeling.com
Hargassner GesmbH .	Anton Hargassnerstr. 1 4952 Weng	Tel: +43 (0)7723 - 5274 Fax: +43 (0)7723 - 52745 office@hargassner.at
KÖB- Viessmann Gruppe	Flotzbachstraße 33 6922 Wolfurt	Tel.: + 43 / 5574 6770-0 Fax: + 43 / 5574 65707 office@kob.cc
KWB - KRAFT UND WÄRME AUS BIOMASSE GMBH	Industriestraße 235 8321 St. Margarethen/Raab	Tel:+43(0)3115 6116-0, Fax + 43(0)3115 6116-4, office@kwb.at
GUNTAMATIC Heiztechnik GmbH	Bruck 7, Bruck-Waasen 4722 Peuerbach	Tel.: +43 (0)7276 / 24 41-0 Fax: +43 (0)7276 / 30 31 info@guntamatic.com
RIKA Innovative Ofentechnik GmbH	Müllerviertel 20 4563 Micheldorf	Tel.: 0043 (0)7582 / 686 - 41 Fax: 0043 (0)7582 / 686 - 43
Polytechnik Luft- und Feuerungstechnik GmbH	Hainfelderstr. 69 2564 Weissenbach (NÖ)	Tel: +43 (0)2672 890-0 Fax:+43 (0)2672 890-DW 13
Biokompakt® Heiztechnik GmbH	Froschau 79 4391 Waldhausen	Tel.: +43 7260 4530 Fax +43 7260 45304 gerlinger@biokompakt.com
ITALY		
Termocabi srl	Giuseppe Corbari Via Borghisani 13 26035 Pieve San Giacomo (CR)	Tel: +39 0372 640033 Fax: +39 0372 640354 termocabi@termocabi.it
KWB Italia srl	Horst Stuffer Via T. Edison 15 39100 Bolzano	Tel: +39 0471 053333 Fax: +39 0471 053334 info@kwbitalia.it
Ecoenergie srl	Matteo Pippa Via Leonardo da Vinci 11 36066 Sandrigo (VI)	Tel: +39 0444 751132 Fax: +39 0444 758386 info@ecoenergie.it
ECOMECC	Luca Canovi Via Palladio 1 37063 Isola della Scala (VR)	Fax: +39 - 0457300175 ecomecc@nuovacft.it

Name	Address	Contact details
SPAIN		
Hargassner Ibérica SL	Ciudad Tecnológica Valnalón C/ Hornos Altos, s/n 33930 - Langreo - Asturias	Tel: 984 28 19 65 Fax: 984 28 16 21 info@hargassner.es www.hargassner.es
INJOCA	Pol. Ind. Los Pozuelos, Parc. 47 23660 Alcaudete (Jaén)	Tel: 953708036 www.injoca.es
RCB	Calle: 32 nº 119 Catarroja, 46470 Valencia	Tel: 961270450 Fax: 961267211 rcbboiler@telefonica.net www.calderasrcb.com
LASIAN Tecnología del Calor, S.L.	Políg. Ind. Las Norias, parcela n.º 7 50450 Muel (Zaragoza)	Tel: 976 140 600 Fax: 976 140 522 info@lasian.es www.lasian.es
ÖKOFEN España	Ingeniería de Energías Renovables S.L. Ctra de Villagarcía Lugar de Cachapal, Campañó 36157 Pontevedra	Tel. +34 986 090 288 Fax. +34 687 822 626 info@emisioncero.es www.emisioncero.es
KWB España	HC Ingeniería S.L C/ San Quintín 10, 2º Izda 28013 Madrid	Tel: +34 91 548 30 25 info@hcingenieria.com www.hcingenieria.com
SWEDEN		
Ariterm Group AB	Flottiljvägen 15 392 41 Kalmar	Tel +46 (0) 480-442850 Fax +46 (0) 480-442859 info@ariterm.se
Hotab	Hedentorpsvägen 16 291 62 Kristianstad	Tel. 044 - 21 84 00 info@hotab.se www.hotab.se
Agromat	AGROMAT Sweden AB Gottåkrav. 14 B 236 41 Höllviken	Tel.: 070- 600 48 00 FAX: 040- 45 05 20 agromat@telia.com www.agromat.se
Järnforsen Energi System AB	Ryttarevägen 18A 302 62 Halmstad	Tel: 035- 17 75 50 Fax: 035- 17 75 59 info@jf-energi.se
KMW ENERGI i Norrtälje AB	Baldersgatan 16 B 761 21, Norrtälje	Tel: 0176-20 56 00 info@kmwenergi.se
Petrokraft AB	Gräddgatan 3 412 76 Göteborg	Phone +46 31 83 06 80 Fax +46 31 40 16 59 www.petrokraft.com

Name	Address	Contact details
FINLAND		
Ariterm Oy	Uuraistentie 1 41301 Saarijärvi	Tel. +356 14 426 300 ariterm@ariterm.fi
Säätötuli Oy	Keskustie 30 61850 Kauhajoki	Tel: +356 207 299 300 info@saatotuli.fi
HT Enerco Oy	Punojantie 1 42800 Haapamäki	Tel. 010 774 5000 Fax. 010 774 5095
Tulostekniikka Oy	Pietari Brahentie 24 43700 Kyyjärvi	Tel. 010 2299000 Fax. 010 2299009 www.tulostekniikka.com
Metso	Fabianinkatu 9 A 00130 Helsinki	Tel +358 20 484 100 Fax +358 20 484 101 www.metso.com
DENMARK		
Maskinfabrikken REKA A/S	Vestvej 7 9600 Aars	Tel. (+45)98624011 Fax. (+45)98624071 reka@reka.com www.reka.com
HS Tarm A/S	Smedevej 6880 Tarm	Tel. +45 97371511 Fax +45 97372434 info@hstarm.dk www.hstarm.dk
LIN-KA MASKINFABRIK A/S	Nylandsvej 38 6940 LEM ST.	Tel. +45 97341655 Fax. +45 97342017 linka@linka.dk www.linka.dk
Burmeister & Wain Energy A/S	Lundtoftegårdsvej 93A 2800 Lyngby	Tel +45 39 45 20 00 Fax +45 39 45 20 05 info@bwe.dk www.bwe.dk
Twin Heat	Nørrevangen 7 9631 Gedsted	Tel.: +45 9864 5222 Fax.: +45 9864 5244 kontakt@twinheat.dk
Vølund Babcock & Wilcox	Falkevej 2, 6705 Esbjerg	Tel. +45 76 14 34 00 Fax +45 76 14 36 00 www.volund.dk
Aalborg Energie Technic	Alfred Nobels Vej 21 F 9220 Aalborg Ø	Telephone: +45 96 32 86 00 Telefax: +45 96 32 87 00 www.aet-biomass.com

Name	Address	Contact details
GERMANY		
A.P. Bioenergietechnik	Träglhof 2 92242 Hirschau	Tel +49 (0)9608 9230128 Fax +49 (0)9608 913319 info@oeko-therm.net www.oeko-therm.net
Heizomat Gerätebau-Energiesysteme GmbH	Maicha 21 91710 Gunzenhausen	Tel. +49 (0)9836 9797-0 Fax +49 (0)9836 9797-97 info@heizomat.de
WVT Wirtschaftliche Verbrennungstechnik GmbH	Bahnhofstraße 55-59 51491 Overath-Untereschbach	Tel.: 02204 / 9744-0 Fax.: 02204 / 9744 - 27 wvt@bioflamm.de
VKK STANDARDKESSEL Köthen GmbH	Am Holländerweg 21-23 06366 Köthen	Tel.: +49 3496 66 0 Fax: +49 3496 66 605 info@vkkstandardkessel.de
Weiss Kessel-, Anlagen- und Maschinenbau GmbH	Kupferwerkstraße 6 35684 Dillenburg-Frohnhausen	Tel: +49 2771 393 0 Fax: +49 2771 393 294 info@weiss-kessel.de
Nolting Holzfeuerungs-technik GmbH	Wiebuschstraße 15 32760 Detmold	Tel: 05231 9555-0 Fax: 05231 9555-55 info@nolting-online.de
hs energieanlagen GmbH	Am Lohmühlbach 21 85356 Freising	Tel: +49 (0) 8161 - 9796 - 0 Fax: +49 (0) 8161 - 9796 – 49 www.hsenergie.eu

B6 Manufacturers of flue gas cleaning technologies

Company	Product	Type	Range of capacity [kW]	Availability on the market	Website
GERMANY					
Schräder Abgastechnik	AL-Top	E	< 100	x	www.schraeder.com
Karlruhe Institute of Technology	CAROLA	E	< 100	-	www.kit.edu
Schiedel AG	-	E	< 100	-	www.schiedel.de
TH Alternativ-Energie GmbH	Feinstaubkiller	E	< 100	x	www.feinstaubkiller.com
A.P. Bioenergie-technik	-	E	< 100	x (in preparation)	www.oeko-therm.net
OekoSolve (Schräder Abgastechnik)	OekoTube (FUTUTErefine)	E	< 100	x	www.oekotube.ch
RuFF-Kat GmbH	RuFF-Kat	E	< 100	x	www.ruff-kat.de
Spanner Re²	SFF	E	< 100	x	www.holz-kraft.de
Spartherm Feuerungs-technik	Airbox	E	< 100	x	www.spartherm.de
WVT – Wirtschaftliche Verbrennungs-Technik GmbH	Bioflamm® MK	CF	50 - 5000	x	www.bioflamm.de
WVT – Wirtschaftliche Verbrennungs-Technik GmbH	Bioflamm® R	CF	30 - 400	x	www.bioflamm.de
Schräder Abgastechnik	KERA Top	F	< 100	-	www.schraeder.com
Kliewe	Open lamellar filter	F	< 100	-	www.kliewe.de
WVT – Wirtschaftliche Verbrennungs-Technik GmbH	Bioflamm® MF	F	30 - 2000	x	www.bioflamm.de
A.P. Bioenergie-technik	-	F	> 100	x	www.oeko-therm.net

E… electrostatic precipitator; CF… dust precipitator using centrifugal forces; F… dust filtration; FC… flue gas condensation

Company	Product	Type	Range of capacity [kW]	Availability on the market	Website
GERMANY					
Bomat Heiztechnik GmbH	Bomat	FC	40 - 2200	x	www.bomat.de
VVS Umwelttechnik	REITHER	FC	> 100	x	www.vss-ut.de
Bschor GmbH	Ökocarbonizer	FC	22 - 400	x	www.carbonizer.de
AUSTRIA					
Advanced Particle Filters	APSenergy TowerFilter	E	50 - 3300	x	www.apf.ag
Advanced Particle Filters	APSenergy RotaryFilter	E	50 - 2000	x	www.apf.ag
KÖB Holzheizsysteme	KRT	F	> 100	x	www.kob.cc
FINLAND					
Oland Heat Tech.	SPRAY-C	FC	< 100	x	not available
Condens Oy	WESP	FC	> 500	x	www.condens.fi
Ehox-tuote Oy	EHOX		> 1000	x	www.ehox.fi
Denmark					
DK	Bag filter	all	Simas A/S	X	www.simas.dk
DK	Bag filter	all	Filtertek A/S	X	www.filtertek.dk

E… electrostatic precipitator; CF… dust precipitator using centrifugal forces; F… dust filtration; FC… flue gas condensation

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/3/ Pollex A., Zeng, T.: Report on interviews, MixBioPells –project (IEE/09/758/SI2.558286), 2012

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