Biomass Report

IEE/09/758/SI2.558286 - MixBioPells

WP 2 / D 2.3

Biomass report

Author 1: Kristöfel Christa, BE2020+
Author 2: Wopienka Elisabeth, BE2020+

With support of all project partners:

DBFZ – Deutsches Biomasseforschungszentrum
VTT - Technical Research Centre of Finland
SP – Technical Research Institut of Sweden
DTI - Danish Technological Institute
Protecma – Energia Y Media Ambiente S.L.
CTI - Italian Thermotechnical Committee

Supported by the European Commission under the EIE programme

INTELLIGENT ENERGY EUROPE

Table of contents

1 Introduction

According to the worldwide rising energy demand and the increased ambitious climate protection targets, the use of biomass for combustion will gain even more importance than it already has. Since wood is getting scarcer caused by the growing demand in material and energetic use, alternative solid biofuels experience growing interest for energetic utilization. Pelletizing the raw material seems to be the best way to optimize the value chain of solid biomass fuels. Pellets have several advantages like high energy density, homogeneous physical characteristics, easy handling and efficient transportation.

The overall objective of this task was to identify relevant raw materials in the partner countries. Furthermore, fuel parameters that are important for their combustion behaviour will be summarised.

This report gives an overview about the available alternative biomasses in the project partner regions (Asturias, Central Finland, East Sweden, Jutland, Lombardy, Lower Austria, Southern Rhineland – Palatinate) which can be used for pellet production and for combustion purpose. The selection process of these raw materials is described in chapter 3. Furthermore, the potential and the processing as well as combustion relevant properties of the selected raw materials are presented in this report.

2 Method and approach

In order to identify the most relevant raw materials, at first all available and eligible raw materials had been listed. The five most relevant raw materials for each region had been selected based on selection criteria such as market size, relevance for the region, expert opinions, cross-border activities, already existing experiences and suitability for pelletizing (see chapter 3). Therefore BE2020+ prepared a template which was used as a guideline by the project partners.

A comprehensive literature review was performed. Furthermore, the data of the potential and agricultural aspects of the selected raw materials were collected with the help of questionnaires, expert interviews and the results of the investigation on ongoing and previous projects.

2.1 Ongoing and previous projects and literature review

Each project partner was asked to gather information on ongoing and previous projects concerning the topic “raw materials”. Therefore, DBFZ and BE2020+ prepared an excel list as template. The content of the identified projects has been discussed by BE2020+ and the project partners in a bilateral way.

Alltogether more than 100 international, national and regional ongoing and previous projects were identified. These projects mainly provide information about agricultural aspects of several raw materials. In particular, much information on straw, Miscanthus and reed canary grass is available. “REGBIE+” and “Agriforenergy” are two important previous IEE projects.

REGBIE+ (Regional Initiatives Increasing the Market for Biomass Heating in Europe) was launched in January 2007 to strengthen the regional importance of biomass heating. The main aim within REGBIE+ was the of support regional stakeholders in order to make ground for a Regional Biomass Action Plan (RBAP). The project officially ended in June 2009.

Agriforenergy I and II have 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.

These two projects provided important groundwork in the field of awareness rising for the MixBioPells project, though they focus on different key aspects.

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 for the chapter “Production and processing of raw material”. The contributions of the project partners concerning the information about the different raw materials were shortened because of the repetitive content and finally combined by BE2020+. The used references are quoted in the text and listed in the annex.

There are also a lot of national projects presenting the results of combustion tests which had been done by the project partners (→internal database of the project partners). However, the topic pelletizing alternative biomass is only covered in very few projects.

In addition the physical and chemical characteristics which are important for the combustion process have been identified and summarized. The imported sources for the combustion relevant properties are:

- Data from internal database DBFZ
- Data from internal database BE2020+
- Data from internal database CTI
- Centre for Biomass Technology. Videnblade No.: 83, 86, 131, 132
- Fuels for CO_2 reduction in power plants, 2005
- Hartmann et al.: Naturbelassene biogene Festbrennstoffe - Umweltrelevante Eigenschaften und Einflussmöglichkeiten, StMLU, München, 2000 http://www.lfu.bayern.de/energie/biogene_festbrennstoffe/doc/festbrennstoffe.pdf
- Kratzeisen M et al. Applicability of biogas digestate as solid fuel. Fuel (2010), doi:10.1016/j.fuel.2010.02.008 (digestates from biogas plants with wet fermentation technology
- Bränslehandboken. Handbook of fuels. Birgitta Strömberg, 2008.
- PHYLLIS database http://www.ecn.nl/phyllis/
- Biobib database http://www.vt.tuwien.ac.at/biobib/biobib.html

2.2 Interviews

In addition to the literature review and the investigation on ongoing and previous projects, 38 interviews have been conducted. The interviewed persons were also involved in the selection process, so the results of the interviews could be incorporated to the selection of relevant raw materials. In summary, the following main results were obtained:

- The future potential of energy crops and residues from agriculture are considered to be high, especially for straw. Figure 1 shows the raw materials, which were considered as most relevant for combustion purpose in the partner countries.
- Regarding the use of alternative biomass, only few concerns about business competitions exist (competitor to food industry, land use competition).
- There are hardly any cross boarder activities for alternative fuel pellets. However, there are some cross boarder activities of Miscanthus, cereals, straw, grass and hay between Germany and Denmark, Netherlands, Poland.

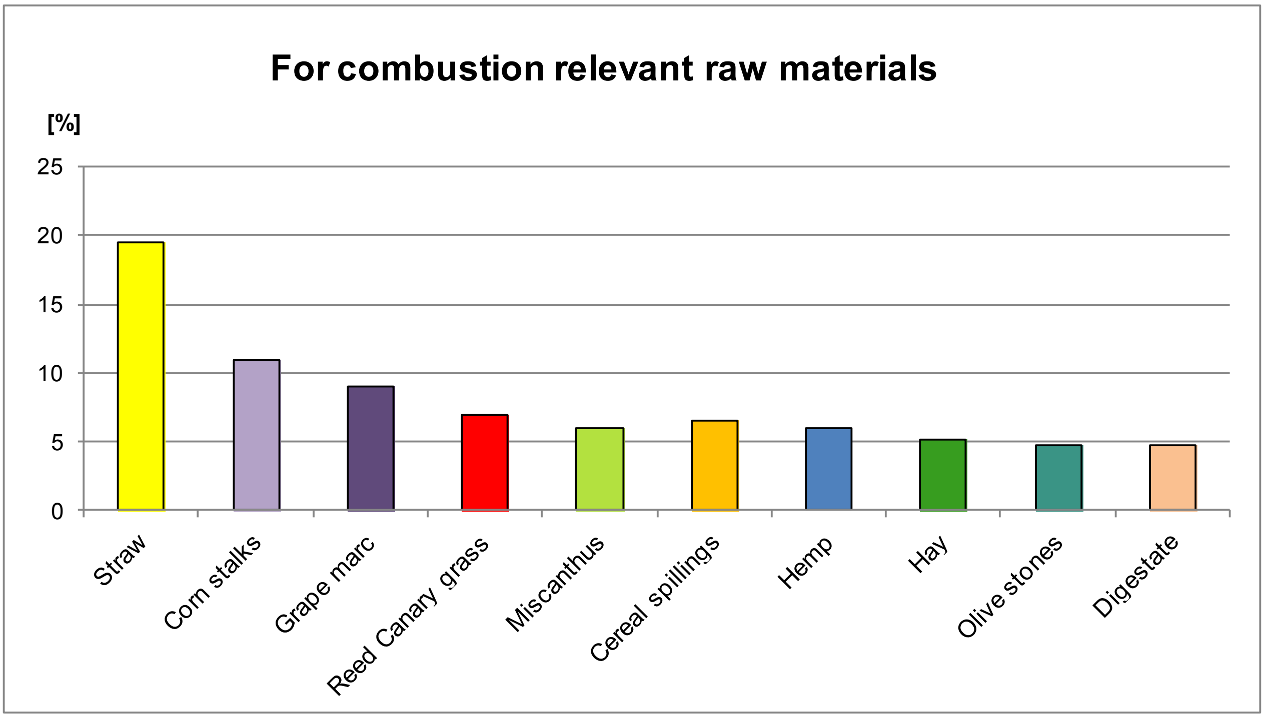

Figure 1: Raw materials, which are considered to be most relevant for the energetic utilization by the interviewed actors in the partner countries (n=38, multiple answers were possible)

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

Austria

The Austrian interview partners considered especially Miscanthus and straw to be relevant for combustion purpose. Furthermore, there is the possibility to use hay, grape marc and mash from breweries for combustion. However, hay can be difficult as fuel and grape marc and mash from breweries are used for forage production.

Germany

The results of the interviews in Germany show, that Miscanthus, straw, hay, grape marc and digestate are considered to be relevant for combustion. In addition, there would be some potential to use residues from the food industry such as olive stones and nutshells, although the available quantities for combustion purpose are very small.

Finland

For the Finish interviewed key actors only reed canary grass and straw appeared relevant for energetic utilization. Besides these two raw materials, peat is used as fuel. Furthermore there are huge amounts of hay available, but this is exclusively used as feed.

Italy

The Italian interview partners think that following raw materials are relevant for combustion:

- Miscanthus
- Corn cobs
- Corn stalks
- Straw
- Hay
- Grape marc
- Cereals
- Vine pruning
- Poplar

However, at the moment for the most of these raw materials no market exists.

Denmark

The results of the Danish interviews show that straw is seen as the most relevant raw material for combustion purposes. In addition, grain screenings and residues from processing of agricultural commodities such as coffee, shea waste, mash from breweries and potato waste could be relevant for energetic utilization. Shea waste is already sold to European power plants. Mash is used as fodder and potato waste is too valuable as fibres.

Sweden

Following raw materials were identified by the Swedish interview partners:

- Miscanthus
- Reed Canary Grass
- Cereals
- Hemp
- Straw
- Corn stalks
- Paulownia

However, Miscanthus, RCG and hemp is seen as the most relevant raw materials for combustion purpose.

Spain

The Spanish interview partners consider Miscanthus, straw, almond shells and residues from the processing of olives and grapes as relevant for the energetic utilization, although there is no market for these raw materials at the moment.

3 Selection of relevant raw materials

In the following, the available raw materials which can be used for pellets production and combustion purpose are presented. The figures show the potential of the selected raw materials that is available for combustion purposes in the particular partner regions. If the data for the respective region was not available, the potential in the whole country is depicted.

3.1 Lower Austria, Austria

In order to identify the most relevant raw materials for Lower Austria, a literature review was carried out and the possible raw materials have been listed by BE2020+. The following raw materials were considered for the selection process:

- Miscanthus
- Straw
- Corn cobs
- Vine pruning
- Hay from landscape gardening
- Mash from breweries
- Recovery of urban green areas
- Cereal spilling

Afterwards, this list of raw materials was discussed at the regional start workshop. The key actors who have participated at the regional start workshop contributed their ideas and opinions on the different raw materials. As a result of the literature review, the discussion with the key actors and the interviews the input for the Table 1 below was obtained. For clarification of open questions also opinions of key actors who have not participated at the workshop were gathered by telephone calls.

For the selection of the five most relevant biomasses the main selection criteria were the available potential of the raw material in Lower Austria as well as the prospective competition between the material and energetic use of the biomass, which should be as low as possible. Furthermore, there are already some experiences with the pelletizing as well as briquetting of straw, hay, Miscanthus and corn cobs in Austria that were taken into account.

Table 1: Selection criteria, Lower Austria

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Expert opinion**	**Others**
Miscanthus	• Medium	• None	• High potential for further cultivation.	• Well established logistic chain. • Experiences with briquetting Miscanthus exist.
Straw	• High	• The cross-border activities are limited to straw for material utilization.	• Combustion problems.	• Well established logistic chain. • Experiences with pelletizing straw exist.
Corn cobs	• First tests with the energetic use of corn cobs have been carried out. • The available potential is high.	• None	• Corn cobs were already used as fuel in former times.	• No competition to food industry.
Vine pruning	• High	• None	• Hardly any experiences with pelletizing vine pruning rexist in Lower Austria.	• Special logistic chain has been developed of Austrian farmers.
Hay from landscape gardening	• High potential	• None	• Difficult to pelletize.	• No competition to food industry.
Mash from breweries	• This raw material is already used in the animal food industry, so there would be a high utilization competition.	• Yes, but only for animal food.	• Would cause high drying costs. • Concerns about the physical and chemical characteristics.	-
Recovery of urban green areas	• Medium	• None	• Is already used for energetic purpose, but pelletizing would not be efficient (high drying costs, heterogeneous)	• Not relevant for the project region.
Cereal spilling	• This raw material is used for animal food production, so there would be a high utilization competition.	• Yes, but only for animal food.	• Logistic chain for energetic use is not well established.	-

In conclusion, considering these criteria, the raw materials straw, hay, vine pruning, corn cobs and Miscanthus were selected (Figure 2).

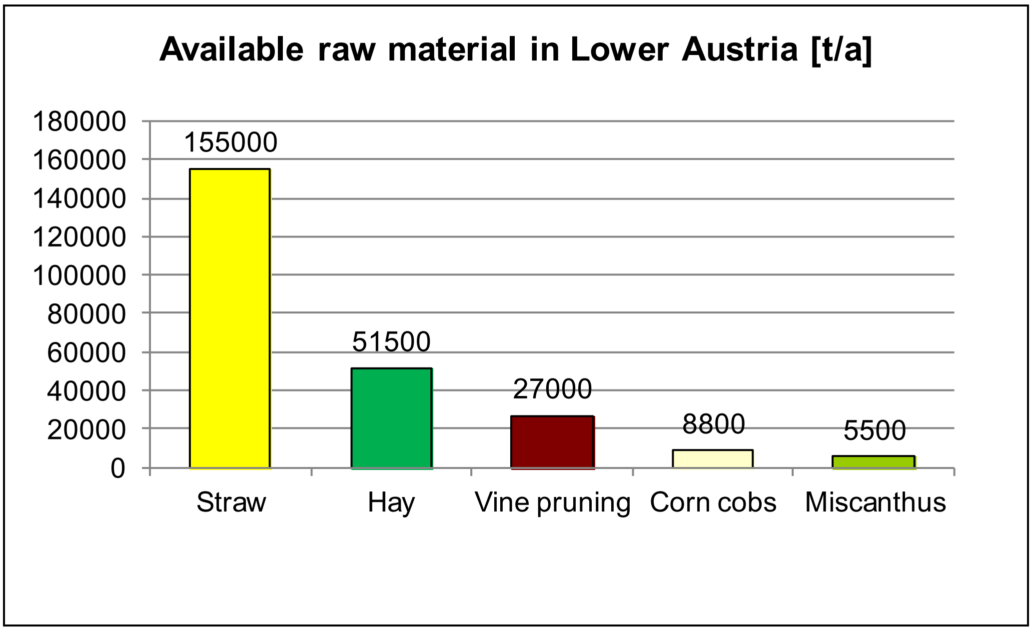

Figure 2: Raw material potentials in Lower Austria
Source: Calculations by Bioenergy2020+

3.2 Southern Rhineland – Palatinate, Germany

The key actors who have participated at the regional start workshop contributed their ideas and opinions on the different raw materials. Additionally, a literature review was carried out. Based on this, different raw materials were selected. For the selection of the five most relevant biomasses the main selection criteria were the available potential of the raw material in Rhineland-Palatinate as well as the prospective competition between the material and energetic use of the biomass, which should be as low as possible. Thus, mainly residues from the agricultural processing industry have been selected. The most relevant raw materials are straw (207,658 t/year), grape marc (157,000 t/year), cereals (119,034 t/year) and rape press cake (65,994 t/year). Furthermore, Miscanthus and digestate were identified as possible raw materials even though the available potentials are low. However, promising potentials are expected in the future if appropriate value chains are available.

Since technical aspects are often constraints for an appropriate energetic use of the raw materials, different criterions were considered to assess the applicability of the raw materials in pelletising and combustion plants. Therefore, experiences from the pelletizing and combustion of alternative biomass pellets of the subcontractor Pusch AG and of DBFZ as well as from literature were gathered. The following criterions were selected:

- Technical aspects for pelletising:
  - compliance with applicable standards (to have access to the common small and

medium scale market in Germany)
low abrasion (to avoid early damages of the dies and increased investments and personal costs for maintenance compared to production of wood pellets)

- Technical aspects for combustion:
  - appropriate ash melting behaviour (to avoid reduced availability of the combustion plant, increased emissions during the combustion process and increased costs for maintenance of the plant)
  - low particulate and gaseous emissions, e.g. CO, NO_x, HCl, SO_2 (to comply with existing emission thresholds in small and medium scale appliances)

An overview of the selection criteria for Germany is presented in Table 2.

Table 2: Selection criteria, Southern Rhineland-Palatinate

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Pelletising characteristics**	**Combustion characteristics**
Straw, cereals	• High	• Yes, to Denmark and Poland for combustion purposes, further trading activities for material use of straw	• compliance with applicable standards is possible • risk of abrasion is increased due to high ash content	• ash melting behaviour is often not technically manageable • particulate emissions are high • gaseous emissions: NO_x, SO_2 not critical, HCl increased risk
Rape press cake	• Medium	• None	• compliance with applicable standards is difficult due to high oil content of material • risk of abrasion is increased due to high ash content	• ash melting behaviour is often technically manageable • particulate emissions are high • gaseous emissions: NO_x, SO_2 not critical, HCl increased risk
Grape marc	• High	• None	• compliance with applicable standards is possible • risk of abrasion is increased due to high ash content	• risks regarding ash melting behaviour are low • results for particulate emissions are not available • gaseous emissions: HCl not critical, NO_x, SO_2 increased risk
Miscanthus	• Low, but promising potential in future if value chain is available	• None	• compliance with applicable standards is possible • risk of abrasion is slightly increased	• ash melting behaviour is often technically manageable • existing thresholds for particulate emissions can be complied with • gaseous emissions: NO_x, SO_2 not critical, HCl increased risk
Digestate	• Low, but promising potential in future if value chain is available and fertilising with digestate is not possible due to high available regional amounts or legal aspects	• None	• compliance with applicable standards is difficult due to less experiences by pelletising of raw materials • risk of abrasion is increased due to high ash content	• risks regarding ash melting behaviour are low • existing thresholds for particulate emissions can be complied with • gaseous emissions: NO_x not critical, HCl, SO_2 increased risk

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

Figure 3 shows the five most relevant raw materials in Southern Rhineland-Palatinate Germany. In addition the energetic use of digestate is considered.

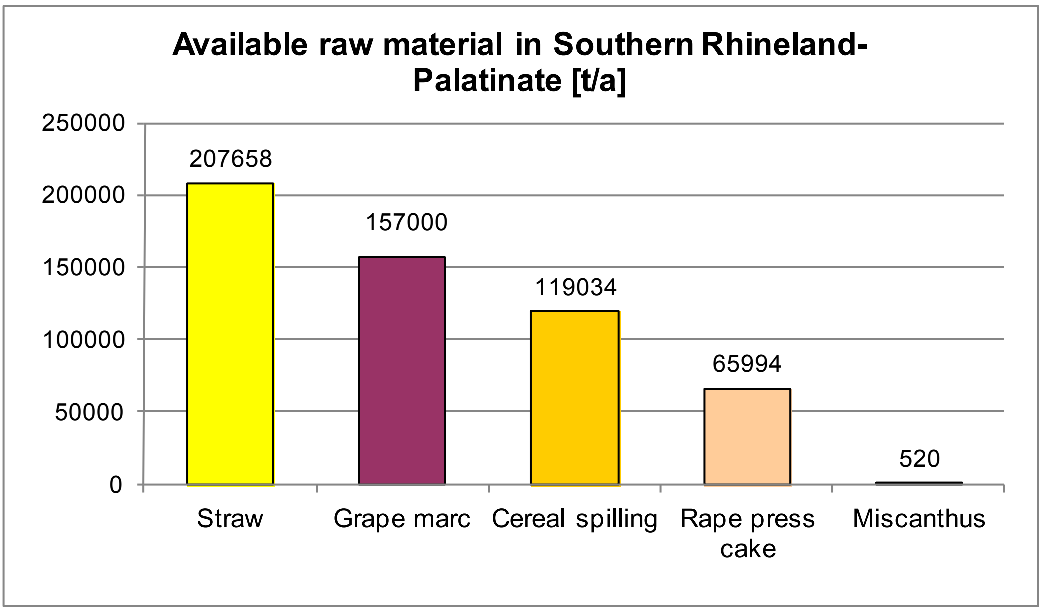

Figure 3: Raw material potentials in Southern Rhineland-Palatinate, Germany
Source: Ministerium für Umwelt, Forsten und Verbraucherschutz 2008. 2009; www.miscanthus.de/flaechen

3.3 Central Finland, Finland

The listed raw materials below were discussed at the regional start workshop. The key actors who have participated at the regional start workshop contributed their ideas and opinions on the different raw materials. As a result of the literature review and the discussion with the key actors the table 3 was obtained.

- Hay
- Reed canary grass
- Straw
- Rape straw
- Rape residues
- Industrial residues
- Peat

For the selection of the five most relevant biomasses the main selection criterion was the available potential of the raw material in Central-Finland. Furthermore there are already some experiences with the pelletizing as well as briquetting of peat, reed canary grass and straw in Finland

Table 3: Selection criteria, Central Finland

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Expert opinion**	**Others**
Reed canary grass	• Medium	• Some over regional borders(radius about 100 km)	• Potential for further cultivation. Spring harvest, water soluble harmful chemicals diminish.	• Well established logistic chain. Experiences with pelletizing and briquetting are available.
Straw	• Low	• None	• Difficult fuel due to higher risk of slagging in the bottom ash, fouling, emissions	• Experiences with pelletizing and combustion of straw exist: Farmers mix straw with wood chips and sod peat.
Peat	• High	• Some, export to Sweden	• Good fuel properties, CO_2-emissions are rather high.	• Well established logistic chain. Experiences with pelletizing, briquetting and combustion exist. .
Rape straw	• Low	• None	• Can be used as fuel alone or mixed with straw.	• Experiences of the pelletizing and combustion exist. Combustion characteristics are similar to RCG and better compared to cereal straw.
Hay	• Very low	• None	• Used as feeding stuff for animals	• High amounts of the raw material for feeding stuff and fuel are available.

Hay was selected due to the high availability, though it is just used as animal feed so far. The other ones were selected based on expert opinions and first positive experiences with pelletizing of these raw materials. Figure 4 shows the potential of the available raw material in Finland. In addition peat can be pelletized and used for combustion. The GTM (Geological Survey of Finland) estimates that there are about 4 Mio. t of peat in Central Finland.

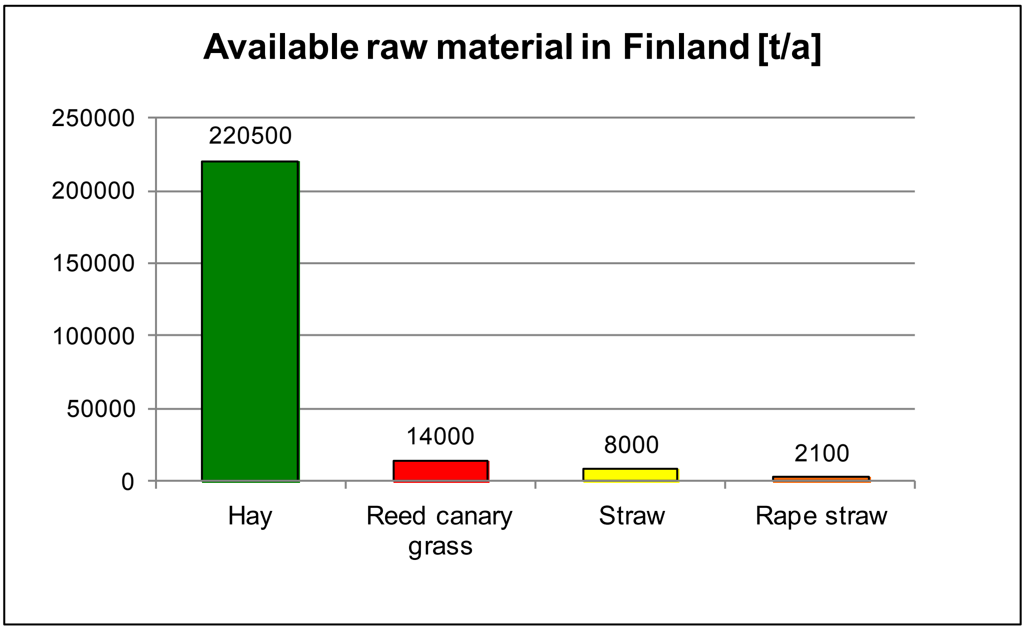

Figure 4: Raw material potentials in Finland
Source: Paapanen et al. 2011

3.4 Lombardy, Italy

Activities and data collected from the literature were included and considered as part of the presentation during the first workshop of MixBioPells. The project partner also reported data regarding the main physical and chemical characteristics of the most important residual biomass available in the country. Based on this information the discussion about the criteria to choose biomass residual representative for Italy has been developed (Table 4). Manufacturers and distributors of biomass pellets explained the problems and issues that need to be considered for the gathering of the raw material. Thus, according to available data and the expert opinion the following main criteria for the selection of representative raw materials of the country were idendified:

- the availability of residues in Italy (amounts);
- the possibility to use agricultural machinery suitable for the management of the product (e.g. harvesting);
- the lack in alternative utilization of the biomass selected and consequently low price resulting from low competition;
- the possibility to recover the residual from small areas or accumulation centers.

Exclusion of available raw materials from the list of the 5 most relevant biomasses is based on the following reasons:

- some products do not reach interesting or significant amount available for energy purposes;
- there are biomasses which are too much spread on the territory and difficult or expensive to collect;
- some materials show difficulties in harvesting operation.

Furthermore, the region Lombardy is well-known as vine growing area, so the use of vine pruning and grape marc seems likely.

Table 4: Selection criteria, Lombardy

Raw material	Biomass availability	Equipment availability of harvesting technologies	Other application of the biomass	Product distribution on the region
Vine prunings	• Several Italian regions have significant amounts	• There are some machines, allowing the harvesting and collection	• The pruning is used as fertilizer	• In general, spread in large amount on territorial districts
Straw	• Very large amounts	• Widely used and available	• Animal feed	• Spread over a large parts of the country
Corn stalks	• Large amounts	• Widely used and available	• The product is used as fertilizer	• Spread over a large parts of the North Italy
Residues from viniculture	• The availability depends on the regions	• There are no particular needs	• None in particular	• Concentrated in plants for the processing of raw materials
Residues from the olive processing industry	• The availability depends on the regions	• There are no particular needs	• None in particular	• Concentrated in plants for the processing of raw materials

The available potential of the selected biomass is shown in Figure 5.

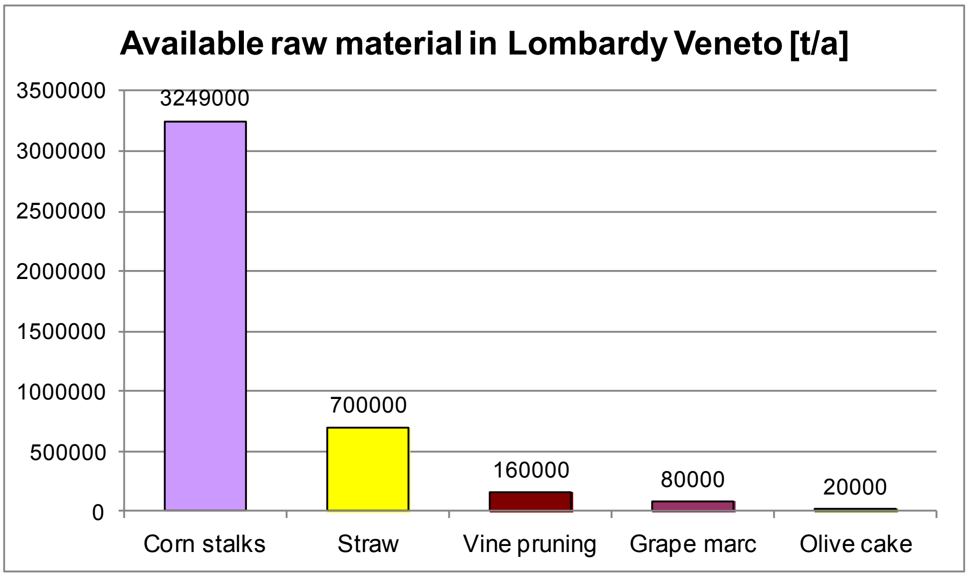

Figure 5: Raw material potentials in Lombardy/Veneto
Source: Motola 2009

3.5 Jutland, Denmark

As a preparation to the regional start workshop on 11.11.2010 a literature study was carried out and presented by Lars Nikolaisen. At the workshop an intense discussion took place in the audience. For the selection of the five most relevant biomasses the main selection criteria are the available potential of the raw material in Jutland as well as the already existing experience using this biomass for energy production (Table 5). In addition there are already experiences with the pelletizing process for straw, shea waste and grain screenings (cereal spilling) on a commercial basis and experience on pelletizing mash and carrageenan waste in pilot scale.

Table 5: Selection criteria, Jutland

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Expert opinion**	**Others**
Straw	• High	• The cross-border activities are limited to straw for material utilization.	• Very good resource. Technology problems in boilers are solved.	• Well established logistic chain. Experiences with pelletizing straw exist.
Shea waste	• High/Medium	• Some export to Europe for the use in power Plants both as pellets and as granulate.	• High potassium content (boiler corrosion). High quality pellets. High heating value.	• No competition to food industry. Easy access to resource.
Carragenan waste	• Medium. Low potential but relevant fuel.	• None	• Good fuel properties to be mixed with biomass having high potassium contents.	• Wet biomass waste. Need instant drying for storing, or direct energy conversion.
Grain screenings	• Medium	• None	• Almost same fuel/ash properties as straw.	• No competition to food industry. Cheap resource.
Mash from breweries	• Medium. Used during winter time as animal food.	• None.	• Good fuel properties to be mixed with biomass having high potassium contents.	• Wet biomass waste. Need instant drying for storing, or direct energy conversion -

Figure 6 shows the potential of the relevant raw material in Denmark.

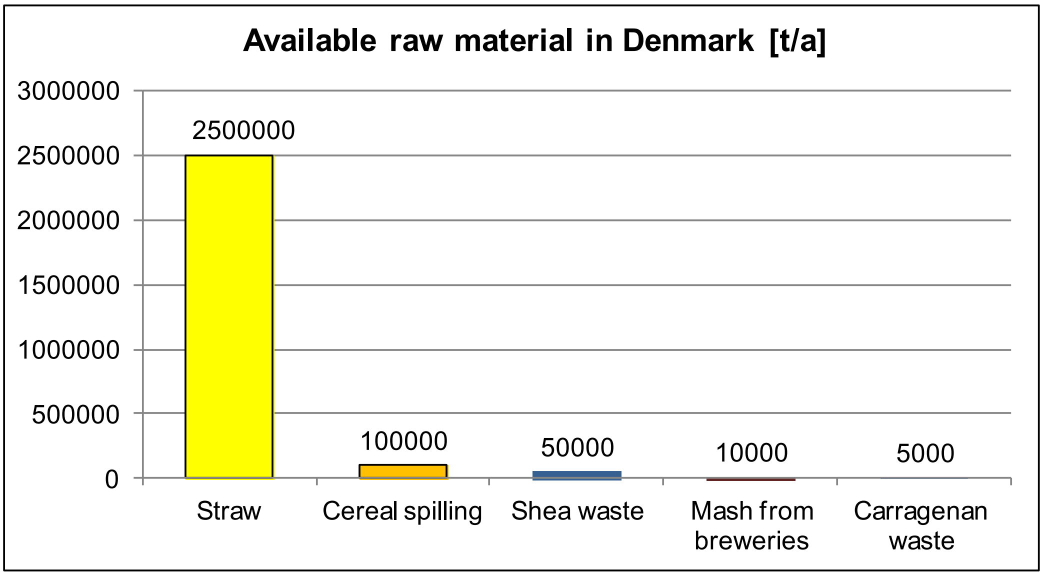

Figure 6: Raw material potentials in Denmark

Danish Technological Institute (DTI)

3.6 East Sweden, Sweden

The technical Research Institute of Sweden (SP) carried out a literature review and web research to identify possible and suitable alternative raw materials for the production of fuel pellets and briquettes in Sweden. The results were presented at the initial workshop. Suitable raw materials for new biomass pellets were then identified during group work and discussions in the initial workshop within WP2. Stakeholders from the whole pellet chain (participants of the workshop) discussed several raw-materials and their applicability with regard to potentials, pelletizing and combustion characteristics. Furthermore, knowledge about new biomass pellets was transferred and experience exchanged. The following materials were discussed: “Clean” waste (recycling centers), garden waste, clearings of roads, railroad tracks and power lines, reed canary grass, straw, hemp, residues from the processing of MDF slices / laminate, chicken feathers, residues from drying and cleaning of grain, animal manure, rapeseed cake, straw, maize, flax. Eventually, 5 raw materials were chosen that are most suitable with regard to potential (availability etc.) and material characteristics (ash content and amount, moisture content etc.) for pellet and briquette production in Sweden (Table 6).

Table 6: Selection criteria, East Sweden

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Expert opinion**	**Others**
“Clean” waste (recycling centers)	• Medium	• None	• Difficult combustion characteristics	• Not relevant for the project (only woody and non woody biomass)
Garden waste	• Medium	• None	• Difficult combustion characteristics	-
Clearings of roads, railroad tracks and power lines	• High	• None	• Difficult combustion characteristics	• Not relevant for the project (only woody and non woody biomass)
Reed canary grass	• High	• None	• High potential for further cultivation and usage.	• Established logistic chain. Experiences with briquetting and pelletising exist.
Straw	• High	• None	• High potential, but difficult combustion characteristics	• Established logistic chain. Experiences with briquetting and pelletising exist, difficult combustion characteristics prevent usage
Hemp	• Medium	• None	• High cultivation costs, difficult for economic viability	-
Residues from the processing of MDF slices / laminate	• Medium	• None	• Difficult combustion	• Not relevant for the project (only woody and non woody biomass)
Cereal spilling	• Medium	• None	• May be used, but only in low fraction mixed with other non-problematic raw material	-
Rapeseed Cake	• This raw material is used for animal food production, so there might be utilization competition.	• None	• Should be better used as protein feed	-
Maize	• Medium	• None	• Better used for food and feed	-

Besides the four biomasses which are shown in Figure 7, cereal spilling could be used for pelletizing and combustion, but now data about the available potential is available.

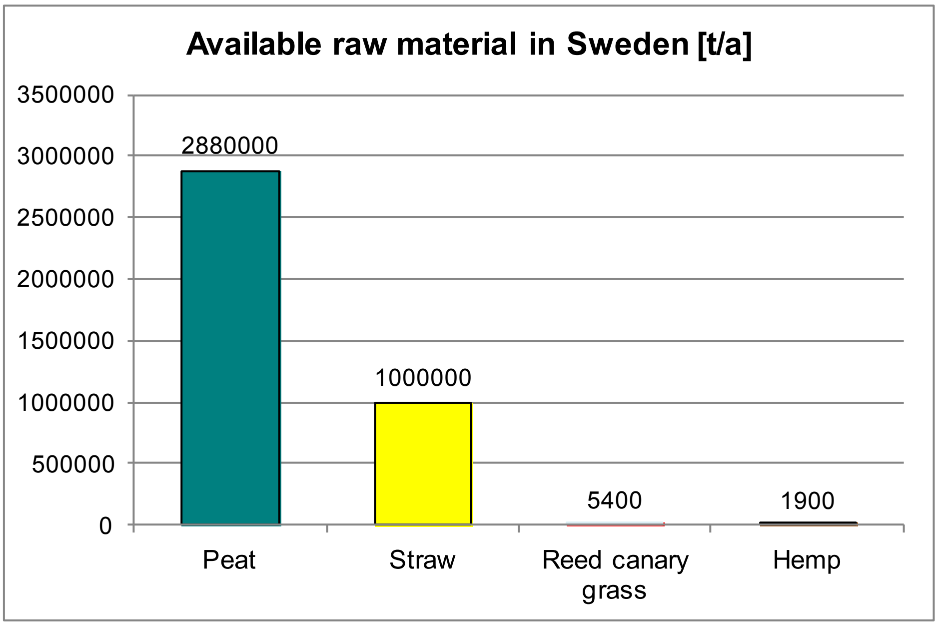

Figure 7: Raw material potentials in Sweden

Source: Technical Research Institut of Sweden (SP)

3.1 Asturias, Spain

The key actors who have participated at the regional start workshop contributed their ideas and opinions on the different raw materials. Additionally, telephone interviews with key actors from research institutes and with policy makers were carried out. Based on this, different raw materials were selected. The region Asturias in Spain only has very limited potential of alternative biomasses for energetic utilisation. Thus, alternative biomasses from whole Spain were considered. The five most relevant biomasses for Spain were selected according to the following criteria: available potential of the raw material with low competition between the material and energetic use of the biomass; typical biomass for this part of Europe with at least locally high significance; already existing utilisation for energy purposes being a surplus but not compulsory. Thus, mainly agricultural residues and residues from the agricultural processing industry have been selected. The most relevant raw materials are straw (960,000 t/year), vine grape residue (820,000 t/year), olive stones (290,000 t/year), almond shells (110,000 t/year) and vine prunings (900,000 t/year). Furthermore, Miscanthus and Paulownia were identified as possible raw materials even if the available potentials are low. However, promising potentials are expected in the future if appropriate value chains are available. There is also high potential of corn cobs, but the harvesting technology is yet not well developed in Spain and no experiences with pelletising of corn cobs are available. An overview of the selection criteria is presented in Table 7.

There are several constraints for an appropriate energetic use of the raw materials resulting from certain characteristics of the alternative biomasses. These characteristics are varying seasonal fuel qualities, ash content and ash melting characteristics, logistic effort, seasonal availability of the biomasses and problematic pelletising characteristics. Thus, further criterions were considered to assess the applicability of the raw materials in pelletising and combustion plants:

- Aspects for pelletising:
    - Fuel availability and costs (distributed or concentrated sources, seasonal availability)
    - Pelletising characteristics (requirement of special technology and additives, varying qualities, abrasion)
- Aspects for combustion:
    - appropriate ash melting behaviour (to avoid reduced availability of the combustion plant and increased costs for maintenance of the plant

Table 7: Selection criteria, Asturias

Raw Material	Selection criteria			
	Market size =Available potential and relevance for the region	**Cross-border trading activities**	**Pelletising**	**Combustion**
Corn cobs	• High	• None	• no experiences available	• burned as a whole, not as pellets
Straw	• High	• Preliminary activities in France and Rumania for energy purposes, further trading activities for material use of straw	• minor seasonal changes of the fuel characteristics • seasonal product but storage possible • risk of abrasion is increased due to high ash content	• ash melting behaviour is often not technically controllable • critical corrosion • risk for boiler damage prevents energetic utilisation in Spain
Olive stones	• High	• None	• strongly varying seasonal fuel characteristics (moisture and oil content) • normally used as such without pelletising • risk of abrasion is increased due to high ash content	• ash melting behaviour is not problematic • low quality olive stone sortiments cause fouling of the boiler
Residues from viniculture	• Medium and only in vine producing regions of Spain	• None	• strongly varying fuel characteristics (moisture content) • seasonal availability, no storage possible • risk of abrasion is increased due to high ash content	• risks regarding ash melting behaviour is high • high ash content • no results known for corrosion
Miscanthus	• Low, but promising potential in future if value chain is available	• None	• minor seasonal changes of the fuel characteristics • seasonal product but storage possible • risk of abrasion is slightly increased	• ash melting behaviour is often technically controllable • risk for corrosion lower than for straw
Vine prunings	• High in vine producing regions of Spain	• None	• minor seasonal changes of the fuel characteristics • seasonal product but storage possible • risk of abrasion is slightly increased	• risks regarding ash melting behaviour are low • risk for corrosion is low
Paolownia	• Low, but promising potential in the future if value chain is available	• None	• minor seasonal changes of the fuel characteristics • seasonal product but storage possible • risk of abrasion is low	• risks regarding ash melting behaviour are low • risk for corrosion is low
Almond shells	• High	• Appoaching foreign market (esp. Scandinavia)	• minor seasonal changes of the fuel characteristics • seasonal product but storage possible • risk of abrasion is slightly increased) • milling prior to pelletising requires high energy input	• risks regarding ash melting behaviour are low • risk for corrosion is slightly increased (depending on the almond processing)

Figure 8 shows the available potential of different raw materials in Spain.

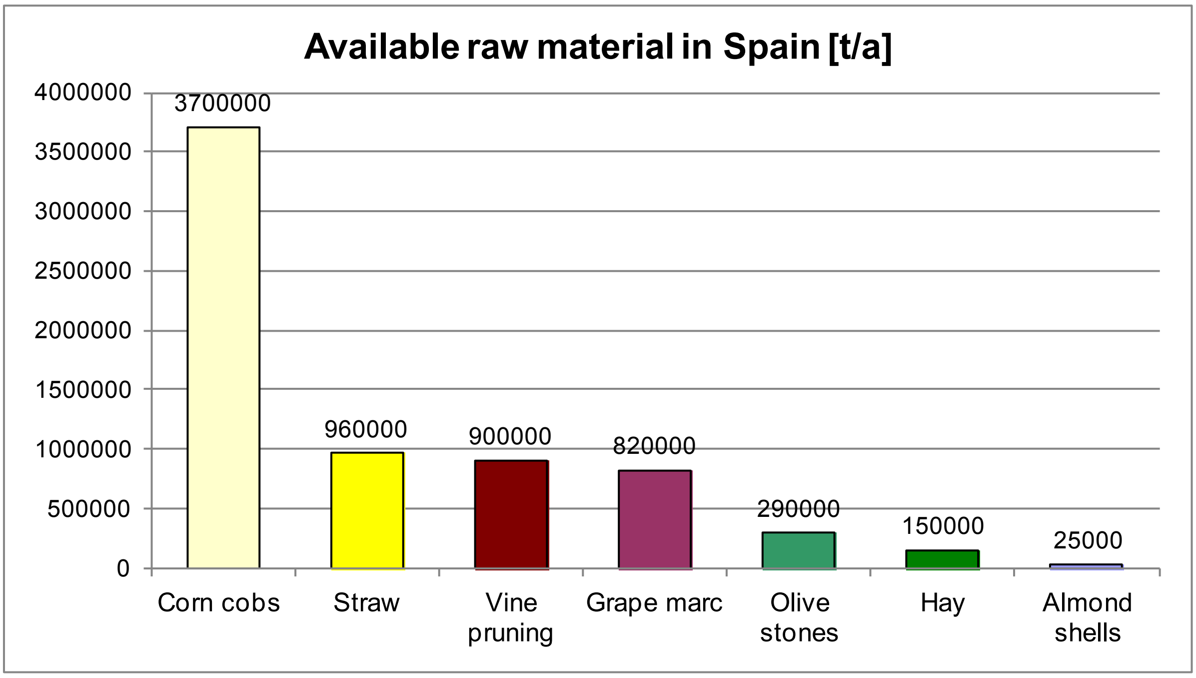

Figure 8: Raw material potentials in Spain

Source: Energia Y Media Ambiente S.L. (Protecma)

4 Production and processing of the raw material

In the following, agricultural aspects and fuel characteristics of the raw materials are specified. Within the Tables fuel properties relevant for combustion are presented. If available, the range of the data is shown. The other values are average values.

4.1 Energy crops

4.1.1 Miscanthus

Over the past years the cultivation of the energy crop "Miscanthus Sinensis Giganteus" for energetic use increased (Figure 9). Miscanthus is a perennial crop with a low demand for fertilizer. Cultivation of Miscanthus starts with the planting of rhizomes. Approximately, 10,000 plants / ha can be grown. In the first two years of cultivation a weed control is necessary. Afterwards, Miscanthus can be harvested up to 20 years (LK Österreich 2006; Defra 2007). Miscanthus has similar needs as corn, so it needs good agricultural soils with a sufficient water supply.

Table 8: Fuel properties of Miscanthus

Miscanthus	
Net calorific value [MJ/kg dm]	17.5-17.9
Ash content [% dm]	2.7-3
Water content [wt.-%]	13.5-14
Ash softening temperature [°C]	820-1,172
N [wt.-% dm]	0.23-0.43
S [wt.-% dm]	0.03-0.09
Cl [wt.-% dm]	0.02-0.13

On well water-bearing soil layers a harvest of 20 t dry matter / ha is possible. However, on average the annual harvest amounts 15 t dry matter / ha. One hectare harvested miscanthus corresponds to 155 loose cubic meter. After the second year, miscanthus can be harvested annually in April with a moisture content of about 14 wt.-% (Defra 2007).

Figure 9: Miscanthus stock in the second year (left side: Spring, right side: autumn)

Source: Thomas Rieger, „ARGE Elefantenwärme"

Miscanthus can be harvested as whole plant if it will be processed for material utilisation (e.g. fibre production, building material, backfill) or chaffed if it is used for energetic purposes. For pelletizing or briquetting usually a corn chopper is used for the harvest (Figure 10). Because of the low water content Miscanthus is suitable for storage. A special designed conveyor belt wagon is used for the delivery. Charging can be done without a fan or without major construction efforts.

Figure 10: Miscanthus chopper in combination with a baling press

Source: Luxemburger Miscanthus-Energie
URL: www.miscanthus.lu

4.1.2 Reed canary grass

Reed canary grass is an energy crop (Figure 11). The perennial grass can grow up to two meters high. The grass is easily grown. Under good conditions it yields up to 7-8 tons of dry matter per hectare. Spring crop of reed canary grass has a low water content and can be processed into briquettes or pellets without drying (Bernesson 2005).

Figure 11: Reed Canary Grass

Source: http://www.bioenergiportalen.se/

Table 9: Fuel properties of Reed canary grass

Reed canary grass	
Net calorific value [MJ/kg dm]	17.5-19.0
Ash content [wt.-% dm]	4.5-6
Water content [wt.-%]	10-15
Ash softening temperature [°C]	1,150-1,650
N [wt.-% dm]	0.3-0.6
S [wt.-% dm]	0.07-0.08
Cl [wt.-% dm]	0.03-0.04

Reed canary grass is a reed-like grass that reproduces by underground offshoot, so-called rhizomes. The grass is durable, winter hard and can be grown on most soils. Greatest yields, however, can be harvested on humus and peat lands. Soil has strong impact on both yield and combustion characteristics. Annually yields on heavy clay soils are lower (6 t dm / ha) and contain higher ash contents (8-10 wt.-%). Mull soils result in higher yields per year (7.5 t dm / ha) and lower ash contents (2-3 wt.-%) (Bernesson 2005).

Reed canary grass develops slowly and should be sown shallow in pure crops (without the involvement of other crops) during spring or early summer. The seedlings are susceptible to dehydration and the first season requires some weed control. Apart from attacks by gall midge reed canary grass cultivations have not shown any problems with pests and/or diseases (Bernesson 2005).

It takes some years before it can be harvested the first time. However, as soon as the grass is established it can give good yields for up to 10-12 years. Fertilisers and machine costs are the main expense in the cultivation of reed canary grass. A fertiliser ration of 40 kg per hectare is sufficient for the first year according to most studies. For the following 2 years 50-100 kg per hectare is recommended depending on soil texture and humus content. From year three it is possible to reduce the fertiliser ration. To reduce costs, some of the fertiliser can also be replaced by mud and ash (Bernesson 2005).

Reed canary grass can be harvested with conventional ley reapers (Figure 12). The grass can be harvested during autumn and stored in windrows in the field during winter, or harvested in spring. Harvesting in spring can start as soon as the frost is gone and the soils are dried up. If the grass is cut in spring, it is important that the green shoots have not grown too high. Impaired growth will occur if the annual shoot is cut off. The green shoots also increase water and ash content in the harvest.

Baling of reed canary grass, either as round bales or square bales, works well. The grass has usually to be stored until winter because reed canary grass is harvested during spring. Reed canary grass is sensitive to moisture and the risk of mold is relatively large for outdoor storage. Therefore, indoor storage is preferable (Bernesson 2005).

Figure 12: Combined harvester and bale compactor of reed canary grass

Source: Paapanen et al. 2011

4.1.3 Hemp

Hemp is an annual herb. Relatively large amounts of seeds (50-140 kg / ha) are used in traditional hemp cultivation for fiber purposes. However, for high returns, significantly smaller amount of seeds can be used. A reduced number of plants per unit area will result in bigger and stronger plants, which can complicate the mechanical harvesting. A sparse population also means that the ability to compete with weeds is reduced. Thus, herbicides may be necessary. For these reasons a seed rate of not less than 20-25 kg per hectare is recommended for cultivations of hemp for energetic purposes. Depending on the quality of the soil, hemp is considered to have a great need for nutrients especially for nitrogen, potassium and calcium. In most soils, a nitrogen ration of 100-125 kg per hectare may be appropriate.

Table 10: Fuel properties of hemp

Hemp	
Net calorific value [MJ/kg dm]	19.1
Ash content [wt.-% dm]	2.3
Water content [wt.-%]	5-7
Ash softening temperature [°C]	1,200
N [wt.-% dm]	1.4
S [wt.-% dm]	0.1
Cl [wt.-% dm]	0.28

Figure 13: Hemp pellets

Source: http://www.bioenergiportalen.se/

Hemp used as fuel should be harvested when most leaves have fallen off, which occurs after frost. A spring crop produces much less than the harvest in late autumn / winter due to losses of biomass during winter and spring. This has several advantages: Overall harvest is facilitated. Furthermore, a large portion is returned to the soil and the ash content of the fuel is reduced because the leaves have particularly high ash content with high levels of potassium which can cause problems during combustion.

Experiences of harvesting hemp for energetic utilisation are still limited. Tall, thick stems with strong fibers make mechanical harvesting a challenge.

Existing (or slightly modified) agricultural machines work for hemp but available technologies are primarily developed and adapted for other types of crops. Practical experiences indicate that a double knife is best for cutting the crop. One problem with the harvesting and management is that the strong fiber can wrap itself around rotating machinery. Hemp harvest wears on cutting or shearing parts.

To grow and harvest hemp is relatively expensive today. If the hemp is processed into briquettes or pellets it is easier to handle and combust and can therefore be sold more expensive. Firing can take place in cheaper boilers.

4.2 Residues from agriculture

4.2.1 Straw

Table 11: Fuel properties of straw

Straw	
Net calorific value [MJ/kg dm]	17-19
Ash content [wt.-% dm]	4.5-7
Water content [wt.-%]	9-15
Ash softening temperature [°C]	800-900
N [wt.-% dm]	0.3-0.8
S [wt.-% dm]	0.06-0.1
Cl [wt.-% dm]	0.03-0.05

Straw is a general term for an agricultural by-product made of dry lignocellulosic materials (stalks, leaves) and derived from different cereal plants. The main component of straw is represented by stalks of plants as rice, wheat, oats and barley. Depending on the kind of crop, the annual production can range from 3 to 5 t / ha of dry matter. Traditional forage harvester equipment is used to pick up the product that is stored in different sized bales. Bulk densities range from 100 to 250 kg / m^3 depending on the kind of harvest machinery (Grüner Bericht 2010).

The straw quantity is strongly influenced by weather conditions. Decisions on agricultural policy will basically affect the quantity of straw that is available for combustion. For example an intensified support of energy crops like rape for esterification can cause a decrease of grain cultivation. The availability of straw is directly linked to the cultivation of cereals and oilseeds. However not all of the straw can be used for combustion purposes. Straw is needed, for example, as bedding on farms. In addition some of the straw should be left in the fields to maintain the humus formation. The weather limits how much straw can be used as fuel. For example, in Sweden rainy autumns make it difficult to harvest enough dry straw. The moisture content of straw is crucial for its quality as fuel. The moisture content does not exceed 20 wt.-% to avoid mold growth and rising of temperature of the bales caused by the metabolism of microorganism. The moisture content needs to be even lower for production of pellets and briquettes of the straw. Weathering and leaching of the straw prior to its compacting will lead to reduced ash content and reduced levels of chlorine and potassium - substances that can cause problems during combustion. (Grüner Bericht 2010; Motola 2009).

When straw is removed from the fields it reduces the humus content of the soil, making it less porous. The harvested straw also removes nutrients from the soil. It is therefore recommended to harvest straw only once per rotation to maintain the soils capacity. If the humus content is low straw should not be harvested at all. Ash disposal can balance some of the nutrient losses. However, some of the nitrogen content is lost during combustion (Grüner Bericht 2010; Motola 2009).

The harvest and logistic technologies are well established. Usually the harvested straw will be compressed to bales (Figure 14). The ash content of pure straw is quite high. Thus, soil uptake during harvest and compacting should be avoided not to further increase the ash content. Outdoor storage is much cheaper than indoor storage, but increases the risk of straw decay and low quality of the straw caused by effects of the weather. However, outdoor storage can lead to better combustion characteristics due to reduced concentrations of potassium and chlorine.

Figure 14: Large round straw bale (left) and round hay baling machines (right).

Source: http://macchinetrattori.wordpress.com

4.2.2 Vine pruning

Vine pruning is a residue of the viniculture. Grapevine planting density ranges from 2,000 to 4,000 plants / ha. On average, annual yields between 1.5 to 2.5 t dry matter / ha are produced. The amount of the vine pruning also depends on the number of stocks / ha, on the grape species and on the age of the grapevine. Pruning takes place from late autumn to late winter. There are different types of harvest machinery. The traditional models collect the product in different sized bales; more recent models produce small branches or sprigs. The bulk density ranges from 150 to 300 kg / m^3 depending on the kind of harvest machinery. Some of the residues are left in the vineyard (Figure 15). The pruning can also be used as fertilizer in spring. However, assuming that the land is managed professionally a removing of the pruning is environmentally neutral (Schildberger 2009; Toscano 2010a, Cristoforetti 2010, Spinelli 2010, Laboratorio Biomasse).

Table 12: Fuel properties of vine pruning

Vine pruning	
Net calorific value [MJ/kg dm]	17.5-18.2
Ash content [wt.-% dm]	2.2-3.5
Water content [wt.-%]	15
Ash softening temperature [°C]	795-1,200
N [wt.-% dm]	0.5-0.75
S [wt.-% dm]	0.02
Cl [wt.-% dm]	0.05-0.07

Figure 15: Vineyard with pruning

Source: URL: http://www.meinbiowinzer.de

Uptake of soil during the harvesting operations increase the ash content up to more than 3 – 4 wt.-%. For the energetic utilisation soil uptake should be avoided to keep the ash content as low as possible. Because of the high water content a storage without drying is impossible. The prunings of vine can dry in the vineyard until March / April. Air dried prunings have a water content of 15 % (1.400 – 1.900 kg / ha air dried prunings of vine, 1.200 – 1.650 kg dm / ha). After the harvesting, the chipped material should be stored under a sheet along the field border (Figure 16). It could be necessary to wait about 3 - 4 weeks, depending on the weather, before milling the material for pellet production. Traditional trailers are used for transport and delivery operations, after the drying step. In general, for chipped material an open trailer is used; for bales, the same transport system as for forage material is used (Schildberger 2009; Peyerl 2007; Toscano 2010a; Schwarz 2008).

Figure 16: Harvesting of grapevine pruning (left) and storage of chipped material (right).

Source: Giuseppe Toscano, Italian Thermotechnical Committee (CTI)

Figure 17: Bale press for vine pruning

Source: Pardatscher 2010

4.2.3 Corn cobs

Corn cobs are residues of the corn production. Before 1960 the corn was harvested by hand and corn cobs were often used as fuel. Nowadays, automatical harvesters are used and the corn cobs are left on the field. An exception is the harvest of corn for seeding purpose at which the whole corn cob is reaped (Figure 18) (LK Kärnten 2010; Handler 2010).

The water content of the corn cobs is usually higher than the water content of the grains of maize. The water content depends on the maize species, the ripeness, the habitat and on the weather. Corn cobs are storable with a water content below 25 wt.-%. Usually, corn cobs have to be dried prior to storage Corn cobs can be harvested with modified harvester threshers. By doing so the straw is left on the field (LK Kärnten 2010; Handler 2010).

Table 13: Fuel properties of corn cobs

Corn cobs	
Net calorific value [MJ/kg dm]	16.5
Ash content [wt.-% dm]	1-3
Water content [wt.-%]	6-7
Ash softening temperature [°C]	1,100
N [wt.-% dm]	0.4-0.9
S [wt.-% dm]	0.03
Cl [wt.-% dm]	0.02

Figure 18: Modified harvester thresher

Source: Handler, FJ-BL

Figure 19: Unload of corn cobs

Source: Handler, FJ-BLT

4.2.4 Corn stalks

Corn stalks are residues of maize crop after harvesting operations. Maize plantation density can reach an average of 60,000 – 80,000 plants / ha and the remains are about 4 t / ha of dry matter. Corn stalks comprise stem, leaves and corn cobs.

Traditional machinery for forage production is used for harvesting and handling operations. The harvesting period is at the end of summer (September – November), after threshing, depending on the region. Bulk density depends on the storage systems; the material is usually stored in round bales (190-260 kg / m^3) using

Table 14: Fuel properties of corn stalks

Corn stalks	
Net calorific value [MJ/kg dm]	16.6-17.5
Ash content [wt.-% dm]	11-17
Water content [wt.-%]	15-18
Ash softening temperature [°C]	1250
N [wt.-% dm]	0.7-0.9
S [wt.-% dm]	0.08-0.1
Cl [wt.-% dm]	n.a.

rotobaler machinery. The moisture content at the harvest time is about 40-50 wt.-% and it decreases to 15-18 wt.-%. The product can be stored in covered hayloft, paying attention to safety standards against risks of fire. Tractors and trailers equipped with a lift can be used. In general, traditional transport machinery used for forage material is sufficient (Candolo 2006,Tenbiore 2010).

4.2.5 Cereal spilling

Cereal spilling consists of damaged grains and seeds, chaff, hulls, weed seeds, etc. recovered from distribution and processing of grain, oilseeds, ley seed, etc. A large part of cereal spilling is used as fuel for drying of grains, some is used as animal feed. Cereal spilling has high ash content and contains relatively large amounts of chlorine and sulphur.

From the energy point of view cereal spilling is a by-product of the processing of cereal. This means that the energy needed to produce the raw material pellets can be set to "zero". Thus, there is no additional energy needed for its production.

Table 15: Fuel properties of cereal spilling

Cereal spilling	
Net calorific value [MJ/kg dm]	16.5
Ash content [wt.-% dm]	9.8-10
Water content [wt.-%]	10-12
Ash softening temperature [°C]	1055
N [wt.-% dm]	1.2-1.7
S [wt.-% dm]	0.2
Cl [wt.-% dm]	0.16-0.3

4.2.6 Hay from landscape gardening

The main goal of nature protection areas such as Natura 2000 areas or biosphere reserves is to maintain and preserve the ecological situation by an extensive, environmental friendly and adapted cultivation of the agriculture.

Figure 20: Unused hay from landscape gardening

Source: Breuss, Thermische Verwertung von Naturschutzheu
URL: http://www.cipra.org/competition-cc.alps/Breuss/

Table 16: Fuel properties of hay

Hay	
Net calorific value [MJ/kg dm]	18.3
Ash content [wt.-% dm]	5.5
Water content [wt.-%]	15
Ash softening temperature [°C]	820-1,150
N [wt.-% dm]	1.6
S [wt.-% dm]	0.04
Cl [wt.-% dm]	0.09

One obstacle in the fulfillment of the conservation requirements is the usability of the harvested biomass in today's intensive agriculture. Due to the late mowing time in the year the hay of abandoned/protected meadows has a reduced feed quality (Figure 20). For that reason it is not suitable for animal feeding. Therefore, other possibilities for its utilisation particularly in biogas or combustion plants are investigated. The annual harvest of hay from extensive cultivated meadows amounts to 3 – 4 tons hay /ha. The water content is abound 15 wt.-% at harvesting time. Due to the fact that the hay from extensive cultivated meadows is a residual product no market price exists (Buchgraber 2004).

As most herbaceous fuels, hay has a low ash melting behaviour and a high ash content. Modifications in the combustion chamber and at the ash removal system are necessary to avoid slagging and fouling (Eder 2008; Pointner 2010).

4.2.7 Rape straw

Rape straw consists mainly of the dried stems. It is commonly left at the field as fertilizer after the harvest of the rape seeds in spring.

The grain-straw ratio of rape is about 1:2.9. Therefore, an average grain yield of about 3.5 tons per hectare and year and 10 tons per hectare and year of rape straw can be achieved during harvest time. 20 – 50 % of the straw should be left at the field. Thus, maximum yields of rape straw are about 5 to 8 t / ha straw per year. Rape straw has a net calorific value of about 18.5 MJ / kg dm and a water content of 45 – 60 wt.-% after the harvest. Thus, rape straw should be dried at the field before it is used as fuel (TFZ 2010).

Table 17: Combustion – relevant properties of rape straw

Rape straw	
Net calorific value [MJ/kg dm]	18.5
Ash content [wt.-% dm]	3.4
Water content [wt.-%]	15-25
Ash softening temperature [°C]	1300
N [wt.-% dm]	1.48
S [wt.-% dm]	0.2
Cl [wt.-% dm]	n.a.

4.3 Residues from the processing of rape, olives and grapes

4.3.1 Rape press cake

Rape press cake is a by-product of the processing of rape to oil. Depending on the pressing technology rape press cake is available as pellets or flakes. Currently, rape press cake is mostly used as protein-rich animal feed.

Rape press cake as fuel has some drawbacks: Rape press cake has high nitrogen content and ash contents, which can cause technical problems. This requires a more expensive and extensive technology and complicates the compliance with existing emission standards (TFZ 2010).

Figure 21: Pellets from rape press cake

Source: http://www.tfz.bayern.de/festbrennstoffe/17482/

Table 18: Fuel properties of rape press cake

Rape press cake	
Net calorific value [MJ/kg dm]	20.84
Ash content [wt.-% dm]	6.5
Water content [wt.-%]	9.07
Ash softening temperature [°C]	860-1,115
N [wt.-% dm]	5.39
S [wt.-% dm]	0.36
Cl [wt.-% dm]	0.01

4.3.2 Grape marc

The grapevine residues (grape marc) are residues from the viniculture and grape processing. Wine production takes place in late summer and early autumn, but the residues are available for many months (until June). There are two types of grapevine residues: wet and leached. The first comes from the grape pressing and contains mainly skins and grape stalks. The second is the product of the wine production In general, for every 100 litres of wine about 18-23 kg residues are produced. The pressing residue contains more than 50 wt.-% of water. The exhausted grapevine residuals have a moisture content of 40 wt.-% approximately. Grapevine residues contain also grapevine seeds that could be removed for oil extraction (seed oil content is about 10-15 %).

Table 19: Fuel properties of grape marc

Grape marc	
Net calorific value [MJ/kg dm]	18.4-20.8
Ash content [wt.-% dm]	3.47-11
Water content [wt.-%]	50-60
Ash softening temperature [°C]	1,300
N [wt.-% dm]	1.8-2.2
S [wt.-% dm]	0.09-0.13
Cl [wt.-% dm]	0.02-0.03

The handling of the grapevine residues is made using trailers, transporters, trucks and skip load. The material can also be transported with conveyor belts. The product could be stored in open spaces or, sometimes, in covered buildings with open side walls. After coupled months, the material tends to degrade (by fermentation) resulting in reduced energy content (Tenbiore 2010, Toscano 2010, Laboratorio).

Figure 22: Grapevine residues heap (left) and conveyor belt for movement of the material (right)
Source: Giuseppe Toscano, Italian Thermotechnical Committee (CTI)

4.3.3 Olive extraction residue

The olive extraction residues are the solid byproduct derived from the olives during the oil extraction. The material contains mainly the skins, the pulp residues (flesh part) and the stones inside the olives (about 25 wt.-%). Although, a large variety of extracting systems are available, two methods are generally employed: traditional pressing and modern centrifuging. Both methods produce a solid residue: wet olive cake. In general, the moisture content is about 50-60 wt.-%.

Sometimes this product is submitted to a chemical extraction to remove the remaining residual oil. Residuals of this operation are exhausted olive cake (without oil) and olive stones. The moisture content of these products is below 18 wt.-%.

Table 20: Fuel properties of olive residues

Olive residue	
Net calorific value [MJ/kg dm]	17.9-18.3
Ash content [wt.-% dm]	9-12
Water content [wt.-%]	35-45
Ash softening temperature [°C]	1,310
N [wt.-% dm]	2.5
S [wt.-% dm]	0.15
Cl [wt.-% dm]	0.06

The density of the product is generally very variable and depends on the kind of material and its moisture content (e.g. 500 kg / m^3 for dry olive cake; 1,200 kg / m^3 for olive stones). The material is available from November to May. The handling of the product is done using trailers, transporters, trucks and skip load. The material is also well moved by conveyor belts. Usually it is stored in closed buildings or in big covered tanks (Toscano 2010, Pattara 2010, Wang 2006, Laboratorio).

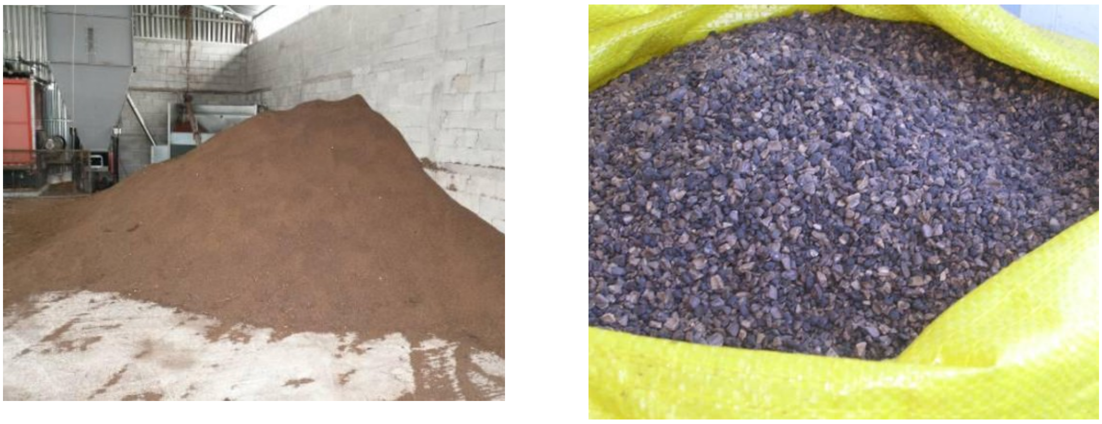

Figure 23: Heap of exhausted olive cake (left) and olive stones (right)

Source: Eubionet 3 - Giuseppe Toscano, Italian Thermotechnical Committee (CTI)

4.3.4 Olive Stones

Spain is one of the main agricultural producers in Europe. Hence, the availability of agro-industrial wastes for combustion is extremely high. However, due to their characteristics not all residues are susceptible to be mixed together with wood. Spain produces 880,000 t olive oil per year (34.1 % of the world production), Italy 500,000 (20.2 %) and Greece 424,000 t (16.4 %). The world production is 2,584,500 t / year.

Figure 24: Olive stones

Source: Energia Y Media Ambiente S.L.(Protecma)

Table 21: Fuel properties olive stones

Olive stones	
Net calorific value [MJ/kg dm]	16
Ash content [wt.-% dm]	< 1
Water content [wt.-%]	12-13
Ash softening temperature [°C]	n.a.
S [wt.-% dm]	< 0.01
N [wt.-% dm]	n.a.
Cl [wt.-% dm]	n.a.

Aproximately 30 % of the weight of the olive belongs to the olive stone. Olive stones have an energetic value similar to wood pellets. Olive trees are harvested once a year, in autumn. Before using olive stones as fuel, they have to be cleaned and dried. The stones can be stored like pellets. They are usually sold in 15 kg bags or loose, like wood pellets, and the silos can be filled pneumatically. The problem with olive stones is the variable quality (Gil 2010).

4.4 Others

4.4.1 Almond shells

The world production of almond shells rises up to 487,000 t / year. The shells are approx. 40 % of the weight of the almond. The almond shells do not need any following processing, as they are already relatively dry. They might be grinded a little, and are used in medium to large boilers. They are sold loose, can be stored like pellets, and transported in large quantities (Gil 2010). There are preliminary activities started for the production and marketing of fuels made of almond shells in Spain.

Table 22: Fuel properties of almond shells

Almond shells	
Net calorific value [MJ/kg dm]	17.9-18.3
Ash content [wt.-% dm]	9-12
Water content [wt.-%]	35-45
Ash softening temperature [°C]	1,395
N [wt.-% dm]	2.5
S [wt.-% dm]	0.15
Cl [wt.-% dm]	0.06

Figure 25: Almond shells

Source: Energia Y Media Ambiente S.L.(Protecma)

4.4.2 Shea waste

The residues of processing shea fruits could be used as fuel. The shea fruit consists of a thin, nutritious pulp that surrounds a relatively large, oil-rich seed from which shea butter is extracted. The fruits resemble large plums and take 4–6 months to ripen. The average yield is 15–20 kilograms of fresh fruit per tree, with optimum yields up to 45 kg. Each kilogram of fruit gives approximately 400 grams of dry seeds.

Table 23: Fuel properties of shea waste

Shea waste	
Net calorific value [MJ/kg dm]	18.5
Ash content [wt.-% dm]	6
Water content [wt.-%]	13
Ash softening temperature [°C]	n.a.
N [wt.-% dm]	2.6
S [wt.-% dm]	0.3
Cl [wt.-% dm]	0.1

Figure 26: Shea waste
Source: Danish Technological Institute (DTI)

4.4.3 Carragenan waste

Carragenan is a macro algae mainly grown in tropical waters (Indonesia) and has been used for years as a food ingredient. When used in food products, carragenan has the EU additive E-number E407 or E407a. The waste from this production is a Ca- and S rich biomass which is good to mix with other biomass. As an example DTI have mixed it with shea waste and it is possible to make a good pellet quality and get a high capacity in the pellet press. Compared to the combustion of shea waste, the mixed pellet will form less amount of KCl in the flue gas, which decreases the corrosion rate in the boiler (DTI 2010).

Figure 27: Carragen-shea pellets

Source: Danish Technological Institute (DTI)

Table 24: Fuel properties of carragenen waste

Carragenen waste	
Net calorific value [MJ/kg dm]	16.6
Ash content [wt.-% dm]	10
Water content [wt.-%]	80
Ash softening temperature [°C]	n.a.
N [wt.-% dm]	0.3
S [wt.-% dm]	0.7
Cl [wt.-% dm]	0.3

4.4.4 Mash from breweries

At the production of beer various residues accumulate which are mostly processed in the animal feed industry. Mash represents with 78.2 % the largest volume share of production related residues. Mash has a water content of about 80 wt.-%.

Mash is available the whole year, in summer on some larger quantities than in winter. The disposal or recycling of mash causes high disposal costs for the breweries. The high energy content of mash in concert with increasing transport and energy costs spur the interest its energetic utilization (Heckmann 1996).

Figure 28: Mash from breweries

Source: Danish Technological Institute (DTI)

Table 25: Fuel properties of mash

Mash	
Net calorific value [MJ/kg dm]	20
Ash content [wt.-% dm]	4
Water content [wt.-%]	80
Ash softening temperature [°C]	n.a.
N [wt.-% dm]	3.3
S [wt.-% dm]	0.2
Cl [wt.-% dm]	0.0

4.4.5 Digestate

The liquid or solid digestate is a residue of the fermentation of biomass into a biogas plant. Because of its high content of nutrients it is most often used as an agricultural fertilizer. Digestate is dried first before being spread on agricultural land. Often digestate is dried with “waste” heat from the biogas power generation (see Figure 29).

Figure 29: Dried digestate

Source: http://de.wikipedia.org/wiki/G%C3%A4rrest

Because the fermentation residues still contain persistent carbohydrate (cellulose, lignocellulose), it can be interesting to use it as a fuel. High mineral content and the contained sulfur and nitrogen compounds (see table 26), however, lead to a relatively high quantity of slag and cause corrosion in the boiler as well as relatively high emissions (Böchzelt 2002).

Table 26: Fuel properties of digestate

Digestate	
Net calorific value [MJ/kg dm]	15.4
Ash content [wt.-% dm]	16.5
Water content [wt.-%]	15.0-20.0
Ash softening temperature [°C]	n.a.
N [wt.-% dm]	2.20
S [wt.-% dm]	0.60
Cl [wt.-% dm]	0.56

4.4.6 Peat

Peat is a material that occurs in nature, consisting of dead plants decomposed in humid conditions at low or no oxygen supply. Peat is composed of organic compounds, mineral particles and chemical precipitates. Sweden, Ireland, Finland and Russia belong to the countries with the largest peat resources worldwide. Fresh peat has a high water content. Therefore, it is necessary to dry it. It has industrial importance as a fuel in some countries, such as Ireland and Finland, where it is harvested on an industrial scale. Due to the environmental impacts, the mining and use of peat is much disputed. Finland classifies peat as a slowly renewable biomass fuel and that position has also been taken by the European Union (IEA 2007).

The ash content of peat can vary in a wide range, from about 3 to 10 wt.-%. It has been shown that peat reduces agglomeration in fluidized bed boilers at co-combustion with other biofuels.

Figure 30: Peat

Source: http://www.chemikus.de/litholexikon/torf.htm

Table 27: Fuel properties of peat

Peat	
Net calorific value [MJ/kg dm]	16.5-21.5
Ash content [wt.-% dm]	4-5.2
Water content [wt.-%]	48.9
Ash softening temperature [°C]	1,100
N [wt.-% dm]	1.2-2.16
S [wt.-% dm]	0.12-0.28
Cl [wt.-% dm]	0.05

5 Combustion – relevant properties of the selected raw material

Compared to woody biomass, non-woody biofuels show considerable differences with regard to fuel properties. In general the ash content of non-woody biomass is higher and at the same time ash melting temperatures are found to be lower. Consequently, improved grate systems are required when using these high-ash fuels, since these properties can lead to problems due to slag formation in the combustion zone. Moreover, combustion conditions might change and cause higher emissions of incomplete combustion, e.g. carbon monoxide (CO) or volatile organic compounds (VOCs).

High levels of nitrogen, sulphur, potassium and chlorine are often found 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 28 gives an overview of the fuel properties relevant for the combustion of the selected raw materials. If available, the range of the data is listed, other values are average values. Single values are especially indicated.

Ash contents vary from below 1 wt.-% up to 17 wt.-% dm. Particularly, high ash contents are found for corn stalks, cereal spilling, grapevine residue, olive residue, almond shells, carragenan waste and digestate. Strong variations are also found for elemental concentrations of N, S and Cl. Relatively high concentrations for all three elements are found for hemp, cereal spilling, shea waste and digestate.

The imported sources for the combustion relevant properties are:

- Data from internal database DBFZ
- Data from internal database BE2020+
- Data from internal database CTI
- Centre for Biomass Technology. Videnblade No.: 83, 86, 131, 132
- Fuels for CO_2 reduction in power plants, 2005
- Hartmann et al.: Naturbelassene biogene Festbrennstoffe - Umweltrelevante Eigenschaften und Einflussmöglichkeiten, StMLU, München, 2000 http://www.lfu.bayern.de/energie/biogene_festbrennstoffe/doc/festbrennstoffe.pdf
- Kratzeisen M et al. Applicability of biogas digestate as solid fuel. Fuel (2010), doi:10.1016/j.fuel.2010.02.008 (digestates from biogas plants with wet fermentation technology
- Bränslehandboken. Handbook of fuels. Birgitta Strömberg, 2008.
- PHYLLIS database http://www.ecn.nl/phyllis/
- Biobib database http://www.vt.tuwien.ac.at/biobib/biobib.html

Table 28: Combustion–relevant fuel properties

Kind of biomass	Net calorific value MJ/kg db	Ash content % db	Water content %	Ash softening temperature °C	N % dm	S % dm	Cl % dm
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	5.0-7.0	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

n.a….not available
[1] Single value

Table 29: Main ash forming elements

Kind of biomass	Al mg/kg (dm)	Ca mg/kg (dm)	Fe mg/kg (dm)	K mg/kg (dm)	Mg mg/kg (dm)	Na mg/kg (dm)	Si mg/kg (dm)	Ti mg/kg (dm)
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

n.a….not available [1] Single value

Table 30: Heavy metals

Kind of biomass	As mg/kg (dm)	Cd mg/kg (dm)	Cr mg/kg (dm)	Cu mg/kg (dm)	Hg mg/kg (dm)	Ni mg/kg (dm)	Pb mg/kg (dm)	Zn mg/kg (dm)
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.

n.a….not available
[1] Single value

6 Annex

6.1 References

Bärnthaler et al. 2008

Bärnthaler,J.; Bergmann, H.; Drosg, B.; Hornbachner, D.;, Kirchmayr, R.; Konrad, G.; Resch, C.: *Technologie, Logistik und Wirtschaftlichkeit von Biogas-Großanlagen auf Basis industrieller biogener Abfälle* Wien: Bundesministerium für Verkehr, Innovation und Technologie, September 2008.

Bernesson 2005

Bernesson, S., Nilsson, D.: *Halm som energikälla - Översikt av existerande kunskap*, SLU Institutionen för biometri och teknik, Uppsala, 2005.

Bernesson 2008

Bernesson, S., Nilsson, D.: *Pelletering och brikettering av jordbruksråvaror- En systemstudie*, SLU Institutionen för energi och teknik, Uppsala, 2008.

Böchzelt 2002

Böchzelt, H.G. et al.: *Möglichkeiten der Wertschöpfungssteigerung durch Abfallvermeidung (biogener Reststoffe) und Nebenproduktnutzung* – Machbarkeitsstudie im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie und des Landes Steiermark, Joanneum Research, Endbericht, 2002

Buchgraber 2004

Buchgraber, K: *Energetische und stoffliche nutzbare Biomasse aus dem österreichischen Grünland*. In: Tagungsband des 10. Alpenländischen Expertenforums, Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, 2004

Candolo 2006

Candolo G. 2006. *Energia dalle biomasse vegetali: le opportunità per le aziende agricole*. Agronomica 4/2006, pag. 26-35.

Candolo 2006

Candolo G. 2006. *Energia dalle biomasse vegetali: le opportunità per le aziende agricole*. Agronomica 4/2006, pag. 26-35 (http://www.crpa.it/media/documents/crpa_www/Progetti/Seq-Cure/Candolo2.pdf)

Canestrale 2007

R. Canestrale, *Residui e scarti: tra ipotesi e realtà.* Il Divulgatore n° 1-2/2007 (http://www.ildivulgatore.it/pdf/2007/01-art3.pdf)

Cristoforetti 2010

Cristoforetti A., Silvestri S., Toscano G. Le potature di vite in caldaia superano i test di emissioni. Informatore Agrario 16/2011, pag. 29-32.

Database Laboratorio Biomasse - Università Politecnica delle Marche, www.biomasslab.it

Defra 2007

Defra (Hrsg.): "Planting and Growing Miscanthus - Best Practice Guidelines For Applicants to Defra's Energy Crops Scheme, 2007

Eder 2008
Eder, G. at al: *Machbarkeitsstudie über die Brikettierung und die thermische Nutzung von Landschaftspflegeheu in Kleinfeuerungsanlagen*, Endbericht, BE2020+ (Hrsg.), Wieselburg, 2008

Gil 2010
Gil, Javier: *Energia de la Biomasa*, 2010. URL: http://www.bestresult-iee.com/Lists/public_deliverables/Attachments/41/Biomass.pdf.

Grüner Bericht 2010
Lebensministerium (Hrsg.): *Grüner Bericht 2010 - Bericht über die Situation der österreichischen Land- und Forstwirtschaft*, Wien, 2010

Hadders et al. 2001
Hadders, G., Arshadi, M., Nilsson, C., Burvall, J.: *Bränsleegenskaper hos spannmålskärna - Betydelsen av jordart, sädesslag och sort*, JTI Institutet för jordbruks- och miljöteknik 2001, Uppsala, 2001.

Handler 2010
Hander, F et.al.: *Analyse eines Verfahrens zur Maisspindelernte*, In: VDI-Berichte/VDI-Tagungsbände Nr. 2111, Landtechnik AgEng 2010 - Partnerschaften für eine neue Innovationspotenziale, VDI Verlag GmbH: Düsseldorf 2010

Heckmann 1996
Heckmann; M.: *Energetische Nutzung biogener Reststoffe der Nahrungs- und Genußmittelindustrie sowie der Land- und Forstwirtschaft unter besonderer Berücksichtigung der thermischen Verwertung*, Diplomarbeit, Technische Universität Wien, 1996.

IEA 2007
International Energy Agency : *Energy Policies of IEA Countries – Finland,* 2007.

Jørgensen und Verwist 2003
Jørgensen U., Verwist T.: "DIAS report – Plant Production 86", 2003.

Junker et al. 2004
Junker, H. Nikolaisen, L et al: *Characterisation of Solid Biofuels,* 2004. PSO project. No 5297.

Laboratorio Biomasse
Database Laboratorio Biomasse - Università Politecnica delle Marche, www.biomasslab.it

LK Kärnten 2010
Tschischej, M: *Es gibt neue Möglichkeiten für Maisspindel*, 09.12.2010
URL: http://www.agrarnet.info; Rubrik Pflanzen, Ackerkulturen.

LK Österreich 2006
Frühwirth, P: *Miscanthus sinensis 'Giganteus' – Chinaschilf als nachwachsender Rohstoff*, Landwirtschaftskammer Österreich (Hrsg.), 2. Auflage, Wien 2006

Motola 2009
V. Motola et al. *Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS.* Tema di ricerca 5.2.5.5 "Censimento del potenziale energetico nazionale delle biomasse." ENEA, 2009.

Motola 2009
V. Motola et al. *Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS.* Tema di ricerca 5.2.5.5 "Censimento del potenziale energetico nazionale delle biomasse." ENEA, 2009
(http://www.enea.it/attivita_ricerca/energia/sistema_elettrico/Censimento_biomasse/RSE167.pdf)

Nikolaisen 1998
Nikolaisen, L et al. *Straw for Energy Production*. Online: www.Videncenter.dk, 1998.

Pardatscher 2010
Pardatscher, K.: *Schnittholzverwertung im Weinbau*, Wuchsbremse und Energielieferant, In: „Obstbau Weinbau“ Fachmagazin des Südtiroler Beratungsringes, Ausgabe 4/2010, Lana (Bozen), 2010 (URL: www.obstbauweinbau.info)

Paapanen et al 2011
Paapanen, T., Lindh, T., Impola, R., Järvinen,T., Tiihonen, I., Lötjönen, T. & Rinne, S., 2011. Ruokohelven hankinta keskisuomalaisille voimalaitoksille. 148 s. + liitt. 5 s.

Pattara 2010
Pattara C., Cappelletti G.M., Cicchelli A. recovery and use of olive stones: commodity,environmental and economic assesment. Renewable and Sustainable Energy Reviewers, 14, 2010, pag 1484-1489.

Peyerl 2007
Peyerl, H.: *Hackschnitzelheizung mit Rebholz*, In: Weinbaumagazin „Der Winzer“, Österreichischer Agrarverlag (Hrsg.), Ausgabe 11/2007, Seite 24 – 27

Pointner 2010
Pointner, C.: *2-jähriges Monitoring einer Kleinfeuerungsanlage für den Betrieb mit Heubriketts*. Endbericht, BIOENERGY 2020+ (Hrsg.), Wieselburg 2010

Progetto TENBIORE 2010
Progetto TENBIORE, Assistenza tecnica per lo sviluppo ed il miglioramento delle tecnologie, metodi e strumenti per un ottimale utilizzo delle biomasse agricole residuali. *http://www.ceta.ts.it/*

Rossi 2007
L. Rossi. *La mappatura delle potenzialità regionali.* Il Divulgatore n° 1-2/2007 (http://www.ildivulgatore.it/pdf/2007/01-art3.pdf)

Schildberger 2009
Schildberger, B.: *Esca – ein uraltes Problem im Weingarten?*, Fachartikel Weinbau, Österreichischer Weinbauverband (Hrsg.), 06.07.2009
URL: http://www.weinbauverband.at, online am: 11.01.2011

Schwarz 2008
Schwarz, H.-P.: *Weinbau und Energie,* Forschungsanstalt Geisenheim, Fachgebiet Technik, Geisenheim, 2008.

Spinelli 2010
Spinelli R., Magagnotti N., Nati C. *Harvesting vineyard pruning residues for energy use. Biosystems engineering* (2010), 105, pag. 316-322

Strömberg, 2005
Strömberg, B.: *Bränslehandboken*, Värmeforsk, Studsvik, 2005.

TFZ 2010
Technologie- und Förderzentrum: *Festbrennstoffe*. Bayerischen Staatsministeriums für Ernährung, Landwirtschaft und Forsten, 2010. URL: http://www.tfz.bayern.de/festbrennstoffe/17482/.

Toscano 2010a
Toscano G. Corinaldesi F., Ash *fusibility characteristics of some biomass feedstocks and examination of the effects of inorganic additives*, Journal of Agricultural Engineering, n.2, June 2010 , pag. 13-20.

Toscano 2010b

Toscano G., *Azoto, Cloro e Zolfo: tre elementi importanti nella qualità del pellet*. Pellet News, n.5 November 2010, pag. 16-17.

Van Loo 2008

Van Loo S., Koppejan J., :*The handbook of biomass combustion & Co-firing*. Earthscan, London, 2008.

Wang 2006

K. Wang et al.: *Waste treatment in the food processing industry*. CRC Press, Taylor and Francis Group, 2006.

Ministerium für Umwelt, Forsten und Verbraucherschutz 2008

Ministerium für Umwelt, Forsten und Verbraucherschutz/ Ministerium für Wirtschaft, Verkehr, Landwirtschaft und Weinbau (Hrsg.): „Kreislaufwirtschaftsland Rheinland-Pfalz“, 2008

Ministerium für Umwelt, Forsten und Verbraucherschutz 2009

Ministerium für Umwelt, Forsten und Verbraucherschutz (Hrsg.): „8. Energiebericht Rheinland Pfalz, Berichtszeitraum 2005 – 2007“, 2009

6.2 Internet References

http://www.bioenergiportalen.se/, *2011-04-27*

www.miscanthus.de, *2011-04-18*

http://www.bestresult-iee.com/Lists/public_deliverables/Attachments/41/Biomass.pdf

6.3 Abbreviations

dm…dry matter

n.a. … not available

wt.-%... percent by weight

6.4

Index of figures

6.5 Index of tables

6.6 List of ongoing and previous projects

Investigation on previous and ongoin projects "Raw material"

Country code	Authors	Year	Original name of project	Name of project in English	Participants	Level	Available language	Short description/evalation of the project etc.
GER	Zeller V.	2011	Basisinformationen für eine nachhaltige Nutzung landwirtschaftlicher Reststoffe zur Bioenergiebereitstellung	Sustainable utilisation of agricultural biomass for energy production	DBFZ, TLL, INL, Öko-Institut	**National**	German	
GER	Harmann H.	2000	Naturbelassene biogene Festbrennstoffe - umweltrelevante Eigenschaften und Einflussmöglichkeiten	Solid biofuels - environmentally relevant properties and influence	TFZ	**National**	German	
GER	Ministerium für Umwelt, Forsten und Verbraucherschutz (Hrsg.)	2009	ENERGIEBERICHT RHEINLAND-PFALZ	Energy report Rhineland-Palatinate	Ministerium für Wirtschaft, Verkehr, Landwirtschaft und Weinbau, Ministerium des Innern und für Sport Ministerium der Finanzen, Ministerium für Bildung, Wissenschaft, Jugend und Kultur, Ministerium für Arbeit, Soziales, Gesundheit, Familie und Frauen, Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht, Statistisches Landesamt Rheinland-Pfalz	**National**	German	
GER	Vetter A.	2010	Regionale Biomassepotenziale zur energetischen Nutzung im Freistaat Thüringen	Regional biomass potetnial for energetic utilisation in the Free State of Thuringia	TLL	**National**	German	
GER	DER NACHHALTIGKEITSBEIRAT DER LANDESREGIERUNG BADEN-WÜRTTEMBERG (NBBW)	2008	Energie aus Biomasse: Potenziale und Empfehlungen für Baden-Württemberg	Energy from biomass: potentials and recommendations for Baden-Württemberg	-	**National**	German	
GER	Reinhardt G.	2005	Nachhaltige Biomassepotenziale in Baden-Württemberg	Sustainable biomass potentials in Baden-Württemberg	IFEU, IUS	**National**	German	
GER	Institut für angewandtes Stoffstrommanagement (IfaS) (Hrsg.)	2004	Studie zur Weiterentwicklung der energetischen Verwertung von Biomasse in Rheinland-Pfalz	Study on development of energy recovery from biomass in Rhineland-Palatinate	IFAS	**National**	German	
GER	Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS) (Hrsg.)	2010	Globale und regionale Verteilung von Biomassepotenzialen	global and regional biomass potentials	DBFZ, ZALF, DLR, ILB, vTI, BMVBS	**National**	German	
GER	Aretz A.	2007	Biomassepotenziale in Deutschland: Übersicht maßgeblicher Studienergebnisse und Gegenüberstellung der Methoden	Biomass potentials in Germany- an overview	Dendrom	**National**	German	
GER	C. Rösch	2007	Energie aus dem Grünland – eine nachhaltige Entwicklung?	Energy from grassland- a sustainable development?	Forschungszentrum Karlsruhe GmbH	**National**	German	
GER	Ministerium für Umwelt, Forsten und Verbraucherschutz (Hrsg.)	2008	Kreislaufwirtschaftsland Rheinland-Pfalz	Recycling economy Rhineland-Palatinate	-	**National**	German	
GER	Programmbegleitung des BMU-Förderprogramms „Energetische Biomassenutzung“ (Hrsg.)	2010	METHODEN zur stoffstromorientierten Beurteilung für Vorhaben im Rahmen des BMU-Förderprogramms „Energetische Biomassenutzung“ TEIL I: TECHNOLOGIEKENNWERTE, GESTEHUNGSKOSTEN, TREIBHAUSGASBILANZEN	Methods for assessing the material flow-oriented projects The BMU program "Biomass Energy" PART I: TECHNOLOGY CHARACTERISTICS, COST, GREENHOUSE GAS BALANCES	DBFZ	**National**	German	

International	Vassilev V.	2010		An overview of the chemical composition of biomass	Bulgarian Academy of Sciences, Institute for Energy, Joint Research Centre, European Commission	**National**	English	
AT	Eder, G.; Luisser, M.	2006	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)	ABC	**National**	German	long term investigation of agricultural biofuels (fuel, ash and combustion properties) in field tests
AT	Eder, G.; Pointner, C.	2008	Energiepflanzenmonitoring des Landes Oberösterreich - Technische Grenzen bei der Verwendung von halmgutartigen Energieträgern in Biomassekleinfeuerungen	Technical limits at the utilisation of lignocellulosic biomass in small scale combustion units	ABC	**National**	German	long term investigation of agricultural biofuels (fuel, ash and combustion properties) in field tests
AT	Eder G., Pointner, C., Reder, M., Wopienka; E.	2008	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	BE2020+	**National**	German	briquetting and combustion experiments with hay
AT	Pointner, C.	2010	2-jähriges Monitoring einer Kleinfeuerungsanlage für die thermische Nutzung von Landschaftspflegeheu	2-year monitoring of a small scale combustion unit fired with hay	BE2020+	**National**	German	Monitoring of combustion experiments with hay
AT	Wopienka, E. et al.	2007	BEStII - Landwirtschaftliche Brennstoffe für Kleinfeuerungsanlagen	BEStII - Agricultural biofuels for small-scale combustion units	B2020+, FJ-BLT, FELMI, ofi, RNS, Vienna University of Technology + 8 company partners	**National**	German	Investigation of fuel properties, combustion properties and cost analysis of various agricultural biofuels
AT	Eder, G., Figl, F., Haberfellner, J., Haslinger, W., Heckmann, M., Musil, B., Wörgötter, M.	2005	BESt - Biomass Economic Strategies	BESt - Biomass Economic Strategies	BE2020+	**National**	German	Investigation of potentials of non-wood biomass
AT	Wopienka E., Carvalho L., Eder G., Emhofer W., Friedl G., Schwabl M.	2008	Strohpellets für Kleinfeuerungsanlagen	Straw pellets for small-scale combustion units	BE2020+	**National**	German	Long-term laboratory experiments with different types of straw pellets (focus: emissions and corrosion)
AT	Strasser, C., Ehrig, R., Wörgetter, M.	2009	klima:aktiv nawaro markt	national promotion programme for material use of renewable resources	BE2020+	**National**	German	Promotion of material use of renewable resources and their market introduction in Austria
AT	Zachhuber, C.; Krotscheck, C.; Selvicka, E.; Birnstingl-Gottinger, B.; Schrimpff, E.; Lauber, V.; Riebenbauer, L.	2006	Landwirtschaft 2020	Agruculture 2020	TU Graz, NATAN, AEE INTEC, ARGE Kreislaufwirtschaften mit Mischkulturen, UNI Salzburg; Ökocluster Oststeiermark	**Regional**	German	Agriculture will become an important supplier of sustainable energy services for society, the project will determine the necessary measures to achieve this state for a concrete regional setting (eastern Styria) by the year 2020.
AT	Liebhard, P.	1997	Miscanthus sinensis 'Giganteus' und Getreideganzpflanzen als nachwachsender Rohstoff für die thermische Nutzung.	Miscanthus sinensis giganteus and cereal plants as a renewable raw material for the thermal use	BOKU, AGES	**National**	German	miscanthus, quality analysis, economic and ecologically reflection about dedicated crops
AT	Eder, G.	2007	Perspektiven des Einsatzes landwirtschaftlicher Biomasse in Kleinfeuerungsanlagen unter besonderer Berücksichtigung von Pelletsbrennstoffen	Perspectives of application of agricultural biomass in small scale boilers in particular consideration of pellet fuels	Johannes Keppler Universität Linz, doctoral	**National**	German	agricultural raw materials in form of pellets for room heating and warm water supply will be indispensable for sustainable energy systems in the future
AT	Heckmann, M.	2006	Analysenbericht EAK: Brennstoffanalyse von Gärresten aus einer Biogasanlage	Fuel Analysis of residues from fermentation during biogas production	BE2020+	**Regional**	German	Fuel Analysis of residues from fermentation during biogas production
AT	Wopienka, E.; Carvalho, L.	2007	Fuel Analysis of Wheat Bran Pellets	Fuel Analysis of Wheat Bran Pellets	BE2020+	**International**	English	Fuel Analysis of Wheat Bran Pellets
AT	Wopienka, E.	2007	Brennstoffanalyse von Pellets aus Rapspresskuchen	Fuel Analysis of press cake from rape seed	BE2020+	**Regional**	German	Fuel Analysis of press cake from rape seed
AT	Wopienka, E.	2008	Fuel Analysis of pellets made of sorghum bicolor	Fuel Analysis of pellets made of sorghum bicolor	BE2020+	**International**	English	Fuel Analysis of pellets made of sorghum bicolor
AT	Figl, F.; Pointner, C.	2006	Combustion Experiments with Pellets from Vineyard Pruning	Combustion Experiments with Pellets from Vineyard Pruning	Bioenergy 2020+	**International**	English	Combustion Experiments with Pellets from Vineyard Pruning
AT	Wopienka E.; Carvalho L.	2007	Combustion Experiments with Wheat Bran Pellets	Combustion Experiments with Wheat Bran Pellets	Bioenergy 2020+	**International**	English	Combustion Experiments with Wheat Bran Pellets
AT	Pointner, C., Wopienka, E.	2008	Combustion experiments with Sorghum pellets	Combustion experiments with Sorghum pellets	Bioenergy 2020+	**International**	English	Combustion experiments with Sorghum pellets

ES	Irene Mediavilla Ruiz, Luis S. Esteban Pascual, Miguel J.Fernández Llorente, Paloma Pérez Ortiz, Juan E.Carrasco García	2007	Pelletization characteristics of different Spanish biomass feedstocks	Pelletization characteristics of different Spanish biomass feedstocks	CIEMAT - CEDER	**National**	English	Wood pellets have become an important renewable energy fuel. Nowadays, the main raw materials used for its production are wood wastes from wood industries. However, this product has other uses in Spain and it is necccessary to look for other possible raw materials. In this work, olive tre pruning, vine shoots, logging residues, wheat straw and pine sawdust (use as reference material) have been assayed, in order to evaluate the milling and pelletizing energy demand and the quality of pellets obtained utilizing different degrees of comminution and different die compression. Te assayed materials require, in general, an intensive particle size reduction and a low die compression and pelletizing at the level of pilot plant, change between 17 kWh/t for olive tre pruning and 272 kWh7t for vine shoots. These values are all above the energy demanda to obtain pellets with pine sawdust (166 kWh/t)
ES	Irene Mediavilla Ruiz, Miguel J.Fernández, L.S. Esteban	2008	Optimization of pelletisation and combustion in a boiler of 17.5 kWt for vine shoots and industrial cork residue	Optimization of pelletisation and combustion in a boiler of 17.5 kWt for vine shoots and industrial cork residue	CIEMAT - CEDER	**National**	English	Wood pellets have become an important renewable energy fuel. Nowadays the main raw materials used for their production are wood wastes from industries. However, these wood wastes have other uses in Spain and it is necessary to look for other possible raw materials. In this work, vine shoots and industrial cork residue were studied as raw materials. The results showed taht pelletisation of vine shoots presented a high energy demand. This energy requirement was reduced with the addition of industrial cork residue. Moreover. industrial cork residue decreased the ash content of pellets and increased their heating value, althought it decrease their physical properties at the same time. Regarding combustion, the addition og industrial cork residue decreased the accumulation of ash in the pellet burner and its sintering tendency. The major conclusion of the work is tat the most appropriate blen to improve pelletisation and combustion processes is 30% wt. of vine shoots and 70%wt. of industrial cork residue.
ES	Juan E. Carrasco	2011	OnCultivos: Proyecto Singular y Estratégico para el desarrollo, demostración y evaluación de la viabilidad de la producción de energía en España partir de biomasa de cultivos energéticos	OnCultivos: Viability of the Commercial Production of Energy from Dedicated Crops in Spain	CIEMAT and further 27 partners (among them ABENGOA, ACCIONA,…)	**National**	Spanish, English	Viability of the Commercial Production of Energy from Dedicated Crops in Spain
ES	Pablo Rodero	2011	Biomasud	Biomasud	AVEBIOM and further 5 partners	**International**	English, Spanish	The project aims to design and implement support mechanisms to help develop a sustainable market for solid biomass. To achieve this, define minimum requirements of sustainability throughout the value chain for this market. In addition,establish a system to audit and certify compliance with these requirements, as well as traceability system that allows you to manage resources from a global perspective.
DK	Gylling, Morten	2001	Energiafgrødeprogrammet	Energy Crop Programme	KU, DTI, FORCE	National	Danish	The project has been carried out as a number of interrelated subprojects, covering the entire production chain of energy crops
DK	Holm, Jens Kai	2008	Fundamental forståelse af pelletering	Fundamental understanding of pelletization	DTU, DONG Energy, DTI	National	English	A theoretical model is presented that describes the development of mechanical forces within the press channel
DK	Nielsen, N.P.K.	2009	Betydningen af råvarens egenskaber ved produktion af træpiller.	Importance of raw material properties for wood pellet production	KU	International	English	The project has shown that several raw material properties affect the pelletizing process.
DK	Panoutsu, P., Nikolaisen, L., Rathbauer, J.	2003	Mulighederne for at nå målet på 45 MTOE energiafgrøder i EU i 2010	Options for achieving the target of 45 MTOE from Energy Cropping in the EU in 2010	CRES, DTI, BLT,	International	English	The report shows, that if all set aside land and 10% of the cereal land is cultivated with energy crops 60 MTOE ca be produced.
DK	Nikolaisen, L.	2002	Kvalitetskarakteristik af biomassepiller	Quality Characteristics of Biofuel Pellets	DTI, FORCE,	National	English	This project documents the technical and economic potential of biofuel pellets produced from mixtures of various biomass

DK	Nikolaisen, L.	2005	CO2 neutrale brændslers anvendelighed i kraftværkskedler	Fuels for CO2 reduction in power plants	DTI, FORCE, DTU, DONG Energy	National	English/Danish	The purpose of the project is to increase the knowledge of bio mixtures fuel quality
DK	Andreasen, P.	1994	Halm- og træpillers anvendelighed som brændsel i mindre fyringsanlæg.	Straw- and wood pellets applicability in small scale appliances	DTI	National	Danish	The aim of the project is to test straw pellets as fuels in small scale boilers
DK	Nikolaisen, L.	1999	Alternative biobrændslers anvendelighed i små fyringsanlæg fra 20 kW til 250 kW	The use of alternative biomass in small scale boilers from 20 kW to 250 kW	DTI	National	Danish	The aim of the project is to increase the knowledge and the experience about the use of energy crops (rye, triticale, miscanthus, peas, willow and rape) in small scale boilers.
DK	Nikolaisen, L. (edt.)	1998	Halm til energiformål	Straw for energy production	DTI, FORCE	International	Danish/English/German	All round technical description of supply chains and combustion technique for straw in both small and large scale boilers.
FI	Alakangas, E.	2000	Suomessa käytettävien polttoaineiden ominaisuudet	Properties of fuels used in Filand	VTT	National	Finnish	Properties almost all bio based rawmaterials used in Finland
FI	Vapo Oy	2010	Vapon turvepellettien ominaisuudet ja laatukriteerit	The properties and quality criterians of Vapo`s peatpellts	Vapo Oy	National	Finnish	Properties of peat
FI	Salo, R. (ed.)	2000	Biomassan tuottaminen kuidun ja energian raaka-aineeksi	The production of biomass for the rawmaterial of fiber and energy	MTK	National	Finnish	Analyses of peat, reedcanary grass, mixes, middle scal combustion of pellets
SWE		2007-2010	ENCROP – Promoting the production and utilisation of energy crops at European level	ENCROP – Promoting the production and utilisation of energy crops at European level	Jyväskylä Innovation Ltd, ETA, GERBIO,ESCAN, S.A., SLU; BOKU, AEBIOM, MTT	**International**	English and Swedish	Aims to boost energy crop business by ◦Increasing the general knowledge, awareness and acceptance about energy crops ◦Disseminating the know-how and results gained in the recent r&d activities ◦Promoting the confidence and collaboration between the actors of energy production chain ◦Developing crop-to-energy business and contract models ◦Dissemination of information about energy crops
SWE	Xiong S., Lötjönen T., Knuuttila K.	2008	Energiproduktion från rörflen Handbok för el- och värmeproduktion	Energy production from reed canary grass A handbook for electricity and heat production	SLU	**National**	Swedish	Energy production from reed canary grass - A handbook for electricity and heat production
SWE	Jonsson Å., Paulrud S., Laitila T.	2010	Betydelsen av olika handlingsalternativ för ökat intresse hos lantbrukare att odla salix och rörflen	Choices of action and its influence on farmers' attitudes regarding willow and canary reed grass cultivation	IVL Svenska Miljöinstitutet AB, Örebro Universitet	**National**	Swedish	In this project different choices of action, in order to increase farmers' interests regarding energy crop cultivation, were analysed by performing a postal survey among farmers. In this survey the Stated Preference (SP) method was used to estimate the farmers' willingness to grow willow and reed canary grass relative to different levels of income, organisation, types of contract, form of delivery, level of education etc.
SWE	Tyskling K.	2008	Biobränsle från det jämtländska jordbruket – en studie om jordbrukarnas alternativkostnad vid odling av rörflen	Biofuel from the agriculture in Jämtland - A study of the farmer□s opportunity cost when cultivating reed canary grass	SLU, Jämtkraft	**National**	Swedish	The purpose of this study is to find out the opportunity cost of the farmland in Jämtland when cropping reed canary grass. The study is restricted to farmland now used for production of pasture. The aim is to satisfy the county administrative board□s production goal of bio energy from farmland. The study is limited within a radius of 70 kilometres from Östersund. A calculation of the farmers□ opportunity cost of the land use with respect to resource allocation, emission restrictions, and production goals is being done.

SWE	Hadders G.	1994	Erfarenheter från vårskördad rörflen	Practical experiences with spring-harvested Reed canary grass	JTI	**National**	Swedish	
SWE	Hadders G.	1989	Fälttorkning av gräs för förbränning	Curing of grass for combustion	JTI	**National**	Swedish	
SWE	Johansson A.	1983	Fälttorkning av energigräs	Curing of energygrass	JTI	**National**	Swedish	
SWE	Emgardsson P.	1982	Fälttorkning av energigräs	Curing of energy grass	JTI	**National**	Swedish	
SWE	Hadders G.	1984	Fälttotkning av Timotej för fastbränsleeldning	Curing of timothy for combustion	JTI	**National**	Swedish	
SWE	Hadders G., Dahlgren L.	1990	Gräs och stråsäd för förbränning	Grass and grain crops for combustion - production costs and market conditions	JTI, LRF	**National**	Swedish	
SWE	Glommers Miljöenergi AB	2008	Rörflensodling en handbok	Reed canary grass cultivation a manual	Glommers Miljöenergi AB	**National**	Swedish	
SWE	Flodén S.	1994	Kostnader för hantering av torrt strå i storbal	Costs for handling of dry grass and straw in big bales	JTI	**National**	Swedish	
SWE	Emgardsson P.	1982	Lagring av energigräs	The storage of energy grasses	JTI	**National**	Swedish	
SWE	Hadders G.	1988	Lagring av gräs för förbränning	Storing grass for combustion	JTI	**National**	Swedish	
SWE	Burvall J.	1997	Rörflen som bränsleråvara	Reed canary grass as a fuel	SLU	**National**	Swedish	
SWE	Olsson R., Rosenqvist H., Vinterbäck J., Burvall J. Finell M.	2001	Rörflen som Energi- och Fiberråvara En System- och Ekonomistudie	Reed canary grass as energy source and fiber - A System and Economy Study	SLU	**National**	Swedish	
SWE	Larsson S., Örberg H., Kalén G, Thyrel M.	2004	Rörflen som energigröda	Reed canary grass as an energy crop	SLU	**National**	Swedish	Experience from full-scale experiments at Biofuel Technology Centre (BTC) in Umeå during 2000-2004. In the years 2000-2004, reed canary grass (RCG) has been cultivated, harvested, stored, upgraded, and combusted at Umeå Biofuel Technology Center (BTC), SLU Röbäcksdalen, Umeå. The entire chain from the field to hot water has been handled by personnel at BTC. Data and experiences from the different handling stages have been continuously collected.
SWE	Hadders G.	1994	Spill vid vårskörd av rörflen	Field loss when haresting Reed Canary Grass in springtime	JTI	**Regional**	Swedish	The report describes three studies of field losses occuring when harvesting Reed Canary Grass in the spring. The studies were conducted at three places in the Lake Mälaren region on three different occasions.
SWE	Olsson R., Landström S., Nilsson C., Schade J., Löfquist B., Paavilainen L., Tulppala J., Finell M., Oravainen H., Paulrud S., Gylling M., Pedersen S.	2004	The Reed Canary Grass project	The Reed Canary Grass project	SLU, UMS A/S, Jaakko Poyry Oy, VTT, Institute of Agricultural Economics in Denmark	**International**	English	Development of a new crop production system based on delayed harvesting and a system for its combined processing to chemical pulp and bio fuel powder, final report
SWE	Hadders G., Johansson S.	1997	Vårskörd av rörflen - vattenhalt i grödan, spill och brandrisker	Spring harvest of Reed canary grass - moisture content, losses and fire risk	JTI	**Regional**	Swedish	Earlier studies have shown that field losses in connection with the harvest of reed canary grass in spring using conventional ley harvesters are very large. The magnitude of the losses can probably be limited by taking account of variation in grass moisture content and avoiding mechanical processing when straw is driest.

SWE	Nilsson D., Bernesson S.	2009	Halm som bränsle - Del 1 Tillgånger och skördetidpunkter	Straw as fuel - Part 1 Available resources and harvest times	SLU	**National**	Swedish	This study had four main objectives: a) to investigate the cultivation areas and yields of different straw crops in the counties of Sweden, b) to present straw:grain-ratios that can be used to estimate the quantities of straw available with respect to the varieties used today, c) to estimate the quantities of straw available in each county for fuel purposes after deducting the quantities used in animal husbandry, and d) to investigate the time of crop harvest.
SWE	Nilsson D., Bernesson S.	2009	Halm som bränsle - Del 2 Fuktegenskaper	Straw as fuel - Part 2 Moisture characteristics	SLU	**National**	Swedish	The objectives of this project were a) to investigate and model the equilibrium moisture content of straw from cereals and oilseed crops, b) to investigate and quantify possible differences in straw equilibrium moisture content between different crops, varieties and threshing methods (shaker and axial flow combines), c) to investigate the moisture absorption rates in straw from different crops and threshing methods, d) to investigate the hysteresis charactristics of straw, i.e. the difference in moisture content between absorption and desorption conditions, e) to develop a model to simulate the moisture content in straw swathes on an hourly basis, and f) to estimate model parameters by monitoring the moisture content in straw swathes in field trials and to evaluate the general validity of the model.
SWE	Nilsson D., Bernesson S.	2010	Halm som bränsle - Del 3 Dynamisk simulering av hanteringssystem	Straw as fuel - Part 3 Dynamic simulation of handling systems	SLU	**Regional**	Swedish	The objective of this study was to identify important factors that influence the choice of logistics system for fuel straw, and to further develop an existing simulation model for straw handling. This model was then applied to a system for delivery of fuel straw to a fictitious small-scale heating plant in the municipality of Sölvesborg in south Sweden.
SWE	Arkelöv O.		Halm som energi i små och mellanstora värmeanläggningar	Straw as energysource in small and medium sized heating systems	LRF Konsult	**Regional**	Swedish	The project's goal has been to demonstrate the capabilities of processing (pelleting) of Straw and Other By-products together with newly developed energy crops. The project will provide answers to questions of both practical applications on issues of economic nature.
SWE	Nilsson D., Bernesson S.	2005	HALM SOM ENERGIKÄLLA Översikt av existerande kunskap	STRAW AS AN ENERGY SOURCE A review of existing knowledge	SLU	**National**	Swedish	The main purpose of this project was to present an overview of the existing techniques for harvesting, transport and combustion of straw in small- and large-scale systems, and to sug-gest research and development projects to increase the future use of straw for fuel purposes in Sweden. In the study, systems for harvesting, transport and storage of big bales (round bales and big square bales), and chaffing, gathering, transport and storage of loose chaffed straw are presented. Alternative systems with field-wafering and whole crop harvesting are also de-scribed. In addition, a study tour was made of fuel straw practitioners in southern Sweden and Denmark in order to review practical experiences.
SWE	Ottosson P., Bjurström H., Johansson C., Svensson S.-E., Mattsson J.E.	2009	Förstudie – Halmaska i ett kretslopp	Pre-study – Straw ash in a nutrient loop		**National**	English and Swedish	This report aims at presenting the basis for recycling ash from energy crops, primarily straw ash, to the agricultural soil from which the biomass has been harvested. The Danish experience with recycling ash is reviewed and the composition of ash with respect to nutrients and trace elements is reviewed. A balance is computed and recommendations for methods to recycle straw ash in Sweden are given.

SWE	Nilsson D.	2010	Simulering och kostnadsanalys av hanterings-system för bränslehalm – tillämpning för en värmeanläggning i Skåne	Simulation and cost analysis of systems for handling of fuel straw - applied to a heating plant in Skåne		**Regional**	English and Swedish	The objective of this project was to develop strategies to reduce the logistics costs for delivery of fuel straw to large thermal plants/co-generation plants. The project adopted a systems perspective that examined the whole chain from harvesting through storage and transport to the heating plant. The method used for the analyses was discrete event simulation. With the help of this simulation technique, the dynamic processes in the entire management chain could be studied, for example by taking account of the weather conditions during the harvest period and by identifying potential bottlenecks in the handling system, etc. Various scenarios were analysed and the costs of these were reported in SEK/MWh free heating plant (ex plant) in order to allow comparisons with other types of fuel. The target groups for the project were owners of heating plants and combined heating and power plants, entrepreneurs, farmers, advisors and others.
SWE	Hadders G., Nillson D.	1993	Storskalig hantering av stråbränslen från jordbruket - Lägesbeskrivning och förslag till utvecklingsinsatser	Large scale handling of grass and straw for combustion - State of the art and a suggestion for a development programme	JTI	**National**	English and Swedish	This report contains a international review, a brief technical outline and a description of the current conditions for producing grass and straw for combustion in Sweden.
SWE	Hadders G., Jonsson C., Sundberg M.	1997	System för hantering av halm i rektangulära storbalar	Handling systems for straw in big rectangualr bales	JTI	**National**	English and Swedish	This report consists of a review and, to a certain degree, an evalaution of technology available for handling straw and dry grass, mainly in rectangualr large bales.
SWE	Johansson R., Larsson T.	2007	Demonstrationsodling av hampa - på åtta gårdar i Västernorrlands län 2007	Demonstration Growing of hampa - on eight farms in the county of Västernorrland 2007	LRF, Biofuel region	**Regional**	Swedish	Trial growing of hampa.
SWE	Sundberg M., Westlin H.	2005	Hampa som bränsleråvara - förstudie	Hemp as a biomass fuel – preliminary study	JTI	**National**	English and Swedish	The aim of this preliminary study was to illuminate certain issues of importance in order to evaluate the potential for hemp as a biomass fuel. One important issue was to judge a realistic yield potential based on field experiment data. We have also tried to gain an understanding of energy-companies' interest in hemp as a biofuel, and which combustion tests are planned. Furthermore, available knowledge and experience concerning hemp harvesting systems has been surveyed.
SWE	Finell M., Xiong S., Olsson R.	2006	Multifunktionell industrihampa för norra Sverige	Multifunctional industrial hemp for Northern Sweden	SLU	**Regional**	Swedish	The goal of this project was to study the oil hemp variety Finola in northern growing conditions. By harvesting seeds in the fall with the scratch table technology and reap strains following spring, all parts (seeds, fiber and wood substances) of the hemp are utilized. Attempts have been made in small trials (in 2003) where oil hemp variety has been compared against three other fiber hemp varieties and in a larger trial of 0.5-1 ha (2003-2005) to study harvest techniques for seed and stock.
SWE	Ivarson J.	2005	Odlingsbeskrivning för industrihampa	Cultivation of industrial hemp	HS	**National**	Swedish	description on how to grow hemp
SWE	Hansson I.	2005	Skördemetoder av industrihampa	Harvest methods of industrial hemp	SLU	**National**	Swedish	I want in my Paper give Swedish growers an insight of which harvesting methods that have been tried in Sweden and how they worked. In Germany, where hemp cultivation have been allowed since the middle of the 1990´s, they have developed specialbuilt harvesting machines that been adapted to German conditions. In Sweden its mainly on Gotland new machines manufactures and experiments has been carried out.
SWE	Jihansson S., Olofsson R.	2009	Utveckling av hampa som energigröda i Mellansverige genom separering av ved och fiber	Development of hemp as an energy crop in central Sweden by separation of the wood and fiber	Föreningen Energinätverket Green4u i Grästorp	**Regional**	Swedish	Purpose and objectives of this project was to proceed with the processing of hemp to increase future viability, leading to a local / regional industrial activity around hemp. The first step was to separate the fiber from the woody parts and then further refine both, product development and production.
SWE	Svensson S.-E., Prade T., Hallefält F., Mattsson J. E.	2010	Utvärdering av metoder för vårskörd av stråbränslen	Evaluation of methods for spring harvest of straw fuels	SLU, Partnerskap Alnarp, ELKV AB, LRF	**National**	English and Swedish	This project examined methods and technical solutions that can be used in the long-term for spring harvesting of straw fuels (direct harvesting of the standing crop) and for making big bales with less losses and better profitability than can be achieved with current multi-step methods.

SWE	Höglund J.	2008	Den Svenska bränslepelletsindustrin: Produktion, marknad och standardisering	The Swedish fuel pellets industry: Production, market and standardization	SLU, SVEBIO	**National**	English	This study presents a broad overview of the Swedish pellet industry. The study had three purposes; to analyze the business situation for the producers, to examine to what extent product standards and environmental certification instruments were used within the industry, and to make an estimate on future potentials and possibilities for the pellet industry.
SWE	Paulrud S.	2004		Upgraded Biofuels - Effects of Quality on Processing, Handling Characteristics, Combustion and Ash melting	SLU	**International**	English	Processing (upgrading) to dry and uniform fuels (briquettes, pellets, and powder) extend the use of biomass wastes as an energy source. Upgrading decreases transportation costs, increases storage capacity, and improves combustion properties. The intention of the present work was to investigate the effect of chemical characteristics and physical characteristics on processing, handling characteristics, combustion, and ash melting, using upgraded biofuels. The raw materials used was spring-harvested reed canary-grass (RCG) and wood residues (stemwood without bark).
SWE	Rönnbäck M., Arkelöv O., Johansson M.	2006	Additiv i syfte att förhindra korrosion och sura utsläpp vid spannmålseldning	Addivtives in order to prevent corrosion and acid emissions during combustion of energy grain	SP, ÄFAB, Energigården	**International**	English and Swedish	The aim of this project has been to investigate wether it is possible to absorb the acuid species through additives added in the fuel or in the supplied air or the flue gas.
SWE	Hadders G., Arshadi M., Nilsson C., Burvall J.	2001	Bränsleegenskaper hos spannmålskärna Betydelsen av jordart, sädesslag och sort	On the fuel quality of cereal grains – Impact of soil composition, cereal species and variety	JTI	**Regional**	English and Swedish	105 samples of seven cereal varieties from winter wheat, winter triticale, barley and oats were analysed. The samples were collected from some hundred locations with varying soil composition in southern Sweden (regions of Götaland and Svealand).
SWE	Rönnbäck M., Johansson L., Claesson F., Johansson M.	2008	Mätning, karakterisäring och reduktion av stoft vid eldning av spannmål	Measurement, characterisation and reduction of dust resulting from the burning of grain cereal	SP	**National**	Swedish	The aim of the project was to characterize and reduce particle emission from combustion of cereal grain by use of additives.
SWE	Berg M., Bubholz M., Forsberg M., Myringer Å., Palm O., Rönnbäck M., Tullin C.	2007	Förstudie - sammanställning och syntes av kunskap och erfarenheter om grödor från åker till energiproduktion	Pre-study – compilation and synthesis of knowledge about energy crops from cultivation to energy production	SP, JTI, Vattenfall, SLU	**National**	English and Swedish	This survey has compiled and synthesized available knowledge and experiences about energy crops from the field to energy production. The aim has been to give a picture of knowledge today, to identify knowledge gaps and to synthesize knowledge of today into future research needs. A proposal of a research plan has been developed for the research programme.
SWE	Myringer Å., Petersen M., Olsson J., Rönnbäck M., Bubholz M., Forsberg M.	2009	Identifiering av energiverkens merkostnader vid förbränning av åkerbränslen samt lantbrukarens möjlighet att påverka bränslekvaliteten	The estimated additional costs for combustion of agro fuel and the potential of farmers to influence fuel quality	SP, JTI, Vattenfall	**National**	English and Swedish	The main objectives of this study were to identify and calculate the additional costs to energy plants of combustion of agro fuels instead of wood chips, and to determine the potential farmers have to influence fuel quality and thus identify parameters that could be used for pricing in the future. The overall aim is to increase the volume of agro fuels produced.
SWE	Paulrud S., Laitila T.	2007	Lantbrukarnas attityder till odling av energigrödor	Farmers' attitudes to energy crops	IVL, Örebro Universitet	**National**	English and Swedish	The purpose of this study was to analyse how farmers value the the charesteristics associated with growing energy crops. An additional goal was to find out the willingness of farmers to grow energy crops relative to different levels of income and subsidies.
SWE	Börjesson P.	2007	Produktionsförutsättningar för biobränslen inom svenskt jordbruk	Production conditions of bioenergy in Swedish agriculture	Lunds Tekniska Högskola	**National**	English and Swedish	The overall aim of this report is to analyse and describe the production conditions of bioenergy in Swedsih agriculture and how these conditions can vary due to different factors. The conclusion is that the potential for producing bioenergy in Swedish agriculture will vary significantly depending on which energy crops are cultivated, which type of agricultural land is utilised and the geographical location of the production. Furthermore, different crop residues and other by-products from agriculture, utilised for energy purposes, will affect the bioenergy potential. To which extent this physical/biological potential will be utilised in the future depends mainly on economic conditions and financial considerations. These aspects are not included in this study.
SWE	Björnberg C.	2007	Ökad produktion av biobränsleråvara – minskat oljeberoende	Increased production of biomass raw material - decreased oil dependence	Norra Skogsägarna, Umeå Energi, Skellefteå Kraft, EU, Länsstyrelsen i Västerbottens län, Lantbrukarnas Riksförbund och Energimyndigheten	**National**	Swedish	The project has aimed to:raise awareness amongst landowners, allow local small businesses have the opportunity to try out new technologies for wood fuel handling, test how fuels behave in boilers, examine the quality of the produced material, improve and streamline machine and logistics, produce a material that is attractive for combustion, solve a problem for private forest, develop measurement technologies for biofuels

SWE	Obenberger I., Thek G.	2010		The Pellet Handbook - the production an thermal utilisation of biomass pellets	IEA, LLT, Uni Graz, BIOS	**International**	English	This handbook addresses all the players of the pellet market – from raw material producers or suppliers, pellet producers and traders, manufacturers of pellet furnaces and pelletisation systems, installers, engineering companies, energy consultants up to the end users – as it tries to provide a comprehensive overview about pellet production, energetic utilisation, ecological and economic aspects, as well as market developments and ongoing research and development. This handbook was written and edited by experienced professionals from IEA Bioenergy Task 32 in cooperation with BIOS BIOENERGIESYSTEME GmbH, Graz, Austria, other IEA Tasks and external experts. It is the first comprehensive guide (over 500 pages) in English language covering all pellet related issues, such as quality standards, application markets and technologies, production methods, logistical aspects, etc.
SWE	Bubholz M., Forsberg M., Gunnarsson C., Rönnbäck M., Olsson J.	2009	Syntes av Värmeforsks forskningsprogram "Grödor från åker till energi"	Synthesis of Värmeforsks´ research programme "Crops from field to energy"	Vattenfall, JTI, SP	**National**	English and Swedish	The aim of this report has been to compile and synthesise progress made during the programme and realization of its aims, as well as to identify the need of further research. This assignment also included carrying out a workshop (Stockholm, November 23rd 2009) in order to identify and specify which research efforts are needed to meet the aim of a well functioning market for agricultural fuels. The report will serve as a basis for Värmeforsk in planning a new research programme.
SWE		2000	Slutrapport Projekt Rörflen	Final report Project Canary redd grass	Sveriges Lantbruksuniversitet, Röbäcksdalen Arvidsjaurs kommun via högskoleprogrammet i Biobränsleproduktion Lokala Markägare	**Regional**	Swedish	Contact, inform and coordinate the landowners who are interested to cultivate unused land with the energy grass reed canary grass. To continuously monitor and record these plantations, and act as coordinator against SLU and Higher education in Biofuel Production Arvidsjaur. A living landscape, ecological thinking and environmentally friendly energy is the main objective of this project.
SWE	Lundmark A., Björk L., Wakelin R., Lundmark B.	2008	Rapport Rörflen	Report Canary Reed Grass	GME, Norut Teknologi	**Regional**	Swedish	Collected experience of the GME work with bioenergy issues 1996 - 2008 based on projects dealing with the topic bioenergy in cold climate
SWE	Sikkema R., Steiner M., Junginger M., Hiegl W.	2009		Final report on producers, traders and consumers of wood pellets	Holzforschung Austria, Utrecht university, Agricultural University of Athens	**International**	English	The study focuses on production, trade and consumption of wood pellets in EU-27, Norway and Switzerland in 2008. Where data is available Russia, Belarus and Ukraine are included.
SWE	Landström S., Wik M.	1997	Rörflen	Canary Reed Grass	SLU	**National**	Swedish	Fact sheet abou canary reed grass
SWE	Olsson R.			Reed Canarygrass Development in Sweden	SLU	**-**	English	Reed canarygrass (RCG), Phalaris arundinaceae, a naturally occurring plant in temperate regions, was first identified as a crop with high biomass production capacity 1987 in the national Swedish bioenergy programme. The search for a suitable production method started 1988 in the project Norrfiber, and the idea about delayed harvest (spring harvest)
ITA	Valter Francescato	2005	Vitis energetica	Energetic grapevine	AIEL, CIA, Te.S.A.F., CATAS, ABEC, Peruzzo, Biocalor	**Regional**	Italian	Cost evaluation of the pruning from grapevine for energy utilisation
ITA	Alessandro Bon	2006	Biocolt	Biocolt	VEN AGR, AREA, CETA	**Regional**	Italian	Production of dedicated crops without energetci input
GER	Marion Elle	2007	REGBIE+	Regional Bioenergy Initiatives Increasing the Market of Biomass Heating in Europe	BAPE, BIOMASA, ESS, ECCB, FAEN, GDE, ITEBE, LEI, ESV, ÖKI, SERA, target, HAWK	**International**	English	Analysis concerning the development and knowledge of the biomass for energy utilisation
ITA	Valter Francescato	2006	Woodland energy	Woodland energy	REG TO, ARSIA, REG ABR, ARSSA, REG FRVG, REG LA, ARSIAL, REG LI, REG MA, ASSAM, REG MO, REG UMB, REG SI	**National**	Italian	Support on the development of the supply agroenergy chain initiatives
AUT	Thomas Loibnegger	2009	Agriforenergy 2	Agriforenergy 2	LK-Stmk, SFI, AIEL, ESS, VTT, CBAO, AEBIOM, 3N - LWK	**International**	English	Development of the support method for connecting stakeholders on the new bioenergy businesses