Large Industrial Users of Energy Biomass

IEA Bioenergy

Task 40: Sustainable International Bioenergy Trade

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Terms

Bioenergy
Bioenergy refers to energy derived from biofuel.

Biomass
Refers to the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Biofuel (=biomass fuel)
Fuel produced directly or indirectly from biomass. The fuel may have undergone mechanical, chemical or biological processing or conversion or it may have had a previous use. Biofuel refers to solid, gaseous and liquid biomass-derived fuels.

Energy biomass
Refers to biomass that is utilised for energy purposes.

Conversion factors
Following conversion factors are used in this report:

Wood pellets	lower heating value 17.0 MJ/kg	
Ethanol	lower heating value 21.2 MJ/l	density 0.8 kg/l
Biodiesel	lower heating value 37.3 MJ/kg	density 0.88 kg/l
Charcoal	lower heating value 22.0 MJ/kg	
Pyrolysis oil	lower heating value 17.0 MJ/kg	density 1.2 kg/l

12 September 2013

Executive summary

The markets of energy biomass are developing rapidly and becoming more international. More and more biomass is sourced from abroad, expecially by large biomass-users. Comprehensive information of the current bioenergy market is an essential factor for contributing the market development.

The objective of the study is to obtain a global overview of the biomass use in industrial and transport sectors and to compose lists of the largest users of energy biomass in the world. Various statistics, databases, reports, and reviews, most of them publicly available, have been utilised during the study to examine plants that either refine biomass for use in transportation and heating purposes or plants that convert biomass into heat and power. The plant lists presented are based on the prevailing situation in the end of the year 2012; due to lack of comprehensive and accurate plant-specific information and rapidly changing situation, the results should be used with care.

Currently, the scope of energy biomass trade is about 1 EJ/yr representing about 5% of the total use of biomass for energy in industrialised countries. Direct trade of biofuels is increasing strongly, whereas indirect trade, which includes imported industrial round wood and wood chips that end up as energy, has been quite stable within the recent years. Especially the trade volumes of biodiesel and wood pellets have been growing lately.

Majority of the biomass energy use, in 2009 66%, is residential use mainly in developing countries. Excluding residential use, the most important user countries are Brazil, the US and India. Biomass use in industrial and transportation sectors concentrates in a small number of countries; in 2009 the fifteen largest users consumed 78% of biofuels in the industrial sector and 95% in the transportation sector. Large plants that process or refine biomass are located primarily in the industrialised countries. The largest plants are producing ethanol and biodiesel; pellet plants are slightly smaller and gasification, torrefaction and pyrolysis facilities are rare and significantly smaller.

Examination on industrial biomass use at plant level shows that recovery boilers and ethanol mills cover together more than half of the use. Global biodiesel production capacity is only slightly smaller than ethanol production capacity, but the utilisation rate is low, about 35%. Comparison of the global capacities (PJ/a) of biomass user plants and the share of the fifteen largest plants in each category at the end of 2012 showed that they are using large amounts of biomass but in no category (with perhaps an exception in the co-firing category) do they dominate the biomass usage. Large new plants can however greatly affect the biomass markets at country level.

The fifteen largest pulverised firing boilers co-firing biomass cover up to 43% of the biomass co-firing capacity. For other boilers as well as wood pellet, biodiesel, and ethanol production the share of the fifteen largest plants is around 10 to 20% of the sectors capacity. Actual use of biomass in the fifteen largests plants exceeds 20% of the sector's use for biodiesel plants, pulverized fuel boilers and CFB boilers, while for other categories, it is close to 10%. Most part of the biomass feed (counted according to the capacity of the plants) used in the largest plants comes from a local source; imported biomass is used primarily in biodiesel plants and pulverised firing boilers. Most part of imported biomass is used in Europe. While the use of raw biomass will likely remain local, the trade of refined biofuels such as bioethanol, biodiesel and wood pellets will likely continue to increase in the near future.

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1 INTRODUCTION

1.1 Starting point

Currently, biomass covers approximately 10% of the global energy supply. Roughly two thirds (34 EJ/a) of the energy use of biomass took place in developing countries for cooking and heating. The remaining use of biomass (about 18 EJ/a) took place in industrialised countries, where biomass is utilised both in industrial applications within heating, power and road transportation sectors and for heating purposes in the private sector, Figure 1-1. In 2009, about 13% of biomass use was consumed for heat and power generation while the industrial sector consumed 15% and transportation sector 4%. The global consumption of biofuels in transportation equaled to about 2% of the total fuels' use of the transport sector. In the same year, biomass use in power, heat and CHP plants was approximately 7 EJ.

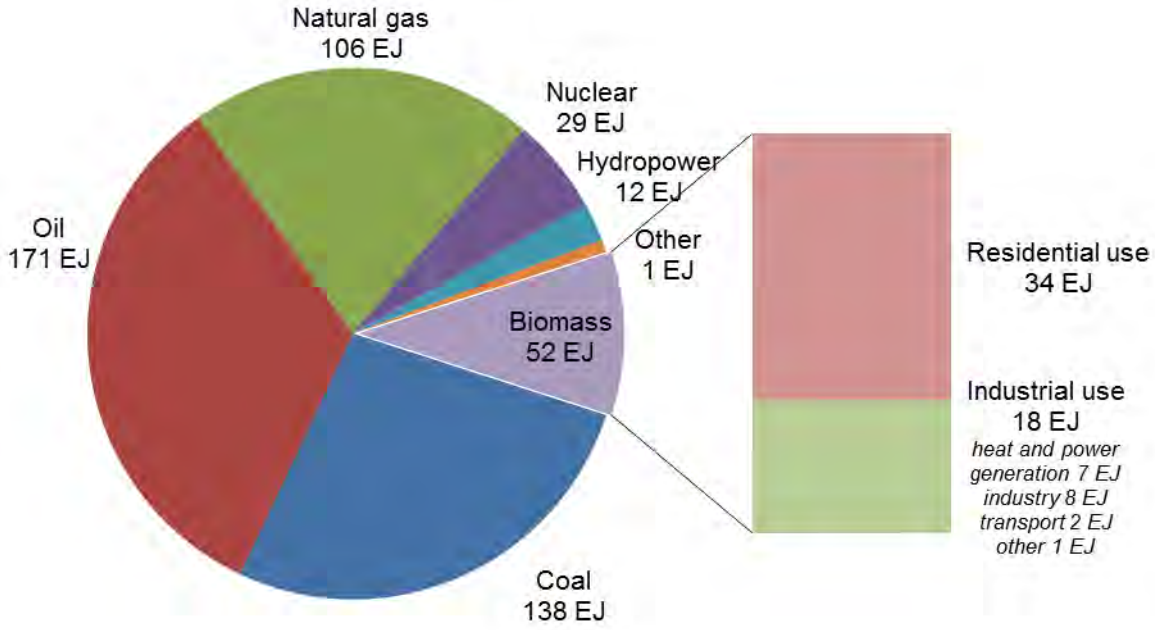

Figure 1-1 Various energy sources in relation to the world's total primary energy supply in 2009. Total primary energy supply was 509 EJ in 2009 [1].

The markets of energy biomass are developing rapidly and becoming more international. The areas from which biomass is procured, especially by large biomass-users, are expanding quickly, and more and more biomass is being sourced from abroad, including from other continents. Comprehensive information of the current bioenergy market is an essential factor for contributing the market development.

IEA Bioenergy Task 40 has a vision to contribute to the development of vital and well-functioning and sustainable bioenergy market. Previously, the global status of the direct and indirect energy biomass trade was carried out within the task in 2008–2009 [2]. That study covers the years 2004–2006. Since then, a few separate market overviews have been published for example for solid biofuels and ethanol, but a comprehensive update on the previous study has not been done. It can be assumed that the biomass market, especially the direct trade, has developed rapidly. During the past years, numerous large-scale green power plants have been introduced worldwide, for example in East Asia and Europe, and most of them are based on imported biomass. It seems that the economically

feasible production of second-generation biofuels will require large or even giant-scale plant sizes. These factors will change the markets of bioenergy and boost the international trade of energy biomass. Especially industrial stakeholders of bioenergy markets (energy, biofuel and technology companies) need to evaluate how the individual projects (plant level) affect the use of biomass.

1.2 Targets of the study

The first objective of the study is to obtain a global overview of the biomass use in industrial and transport sectors. The second aim is to compose lists of the largest users of energy biomass in the world. These lists include both energy producing plants and biofuel production plants. The challenges related to the identifying of the largest industrial users of energy biomass are evaluated. The share of the biomass usage worldwide, biomass trade worldwide and biomass used by large users is investigated using the global biomass usage of 2011 as the base level. Thirdly, the trends of large biomass users are investigated by comparing the current lists to the lists of future projects.

The largest users of energy biomass are listed both at country level and at plant level. At country level, especially the biomass use in transportation and industrial sectors is studied. Large biomass user plants examined in this study include biomass refining and processing for energy carrier purposes (biofuels) as well as biomass conversion into heat and power. Both operating facilities and plants under planning are studied. An effort is made to find out what kind of biomass the large users utilise and whether they use domestic or imported feedstock. The aim is to find out what kind of an influence large biomass users have on the global biomass trade.

1.3 Methodology and implementation of the study

This study has been done using literature, statistics, databases, reports and reviews publicly available and relevant to the study. The used categorisation of the biomass users used in this report is represented in Figure 1-2. The largest users of biomass are assumed to be either plants that refine biomass for use in the transportation sector and heating purposes or plants that convert biomass into heat and power.

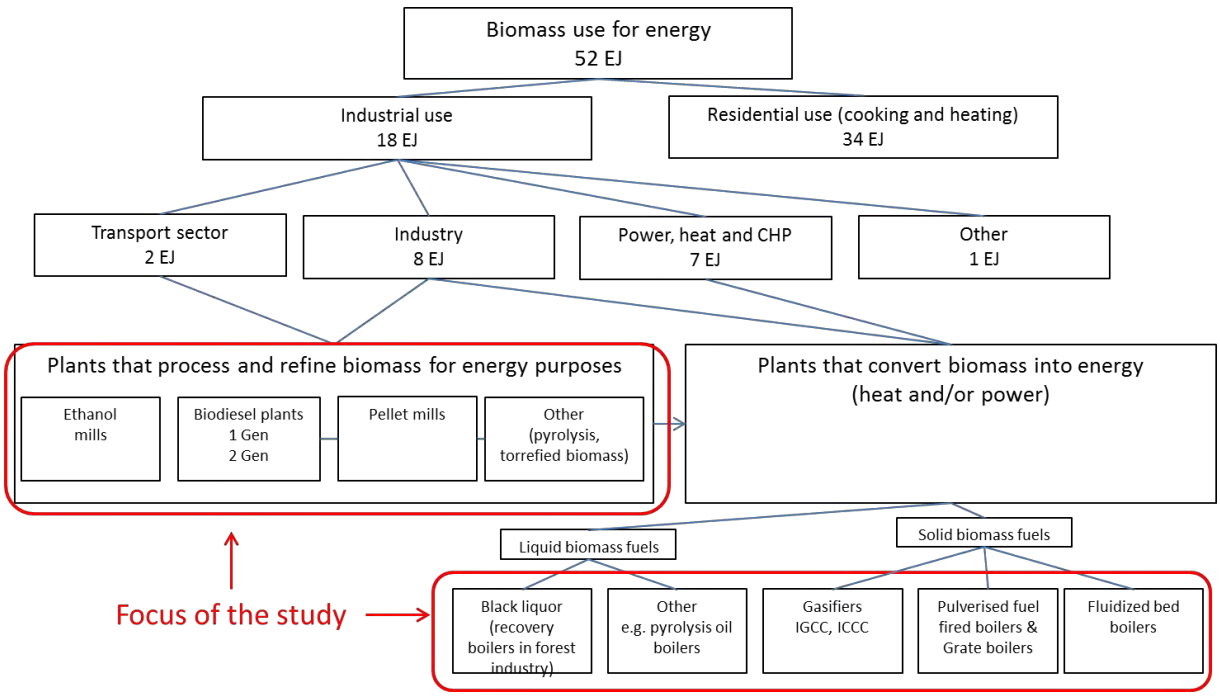

Figure 1-2 Categorisation of biomass users applied in the study. Biomass use figures are from the year 2009.

For reasons mentioned in the previous paragraph, the study concentrates on these categories. Plants that refine biomass include ethanol mills, biodiesel plants, pellet mills and other, such as torrefaction

and pyrolysis plants. Heat and power generation can be divided into plants that use liquid biofuels, such as black liquor boilers and pyrolysis oil boilers, and plants that use solid biomass fuels, such as fluidized bed boilers, pulverised fuel fired boilers, grate boilers and various types of gasifiers. The plant lists presented in this report are based on the prevailing situation in the end of the year 2012. It should be taken into account that: 1) the plant-specific information presented in this report is based on published but sometimes/often unverified information and therefore the results should be used with care, and 2) not all of the new biomass plants under planning and construction will ever be realised and 3) some of the plants operating in 2012 have stopped operating or changed the amount of biomass they use.

The structure of the report is as follows. Section 2 gives an overview of the available data sources on biomass use for energy at country and plant level. In section 3, the status of solid and liquid biofuels trade is updated until the year 2011. Section 4 reviews the biomass use at country level and gives an overview on the largest biomass users at country level. In section 5, an attempt to identify the largest energy biomass processing plants and energy plants using biomass fuels is made. Section 6 presents the large projects under planning or construction related to energy biomass processing and biomass based energy generation. The results and methodology of the study are discussed in section 7, and finally, conclusions are given in section 8.

2 REVIEW OF AVAILABLE STATISTICS AND DATA SOURCES

2.1 Statistics

2.1.1 National energy statistics

National Energy statistics are explored in the case of countries which according to wide-ranging statistics are large users of biomasses, and more specific information is required of the biomass use in industrial and transportation sectors. The availability and accuracy of data differ from country to country. The national energy statistics of various countries such as Finland, Sweden, Germany and Brazil offer accurate information relevant to this study.

In Finland, official statistics, including Energy Statistics, are published annually by Statistics Finland. Energy Statistics include information of the production, consumption, imports, exports and prices of energy as well as information on the investments and emissions related to energy production and consumption. Finnish Forest Research Institute produces annual reports on the use of wood fuels in energy generation. The reports also contain information on the production and consumption of wood pellets and the volume of foreign trade [3].

Swedish administrative agency Statistics Sweden produces official statistics for the Swedish government and other statistical data for different agencies and companies. Swedish Energy Agency is the statistical authority responsible for the official energy statistics in Sweden [4].

German Energy Statistics are produced by the Federal Statistical Office. Energy statistics contain information on the economic situation in energy supply, energy production data and energy use. Statistics on energy production include data on part of the renewable energy sources, such as feeding electricity from renewable sources into the general supply network [5].

Brazilian Federal Government Ministry of Energy and Mines publishes annually Brazilian Energy Balance which contains data of energy supply and consumption, conversion processes and foreign trade [6].

Each European Union Member State has provided a National Renewable Energy Action Plan (NREAP) for the European Commission. The plans present projections for renewable energy development in the member states in order to fulfil the EU target of generating 20% of its energy consumption by renewable sources by 2020.

2.1.2 International statistics

The Energy Statistics Division of the IEA collects energy-related data from both the OECD member countries and countries beyond the OECD. The data of renewable energy in 2009 covers renewable energy production and use in 136 countries. IEA statistics provide country level data on the use and production of solid, gaseous and liquid biomasses and also waste used for energy purposes. Also data on the consumption of biomasses in different sectors for example industrial and transportation sectors, residential use and power and heat generation in each country is available. The industry sector in IEA statistics includes iron and steel, chemicals and petrochemicals, machinery and many others. Energy industry is not included in the industry sector but is presented separately. In addition to the four transport modes which are road, rail, air and national navigation, the transport sector covers pipeline transport [1].

The European Union statistical office in Luxembourg provides statistics at European level. Eurostat energy statistics contain country level information for example on energy production, usage, import and export, and the data covers the 27 European Union member countries and additionally Croatia, Turkey, Iceland and Norway. Data is collected by the member countries and consolidated by

Eurostat. The data is collected from countries by an annual questionnaire, and the accuracy of it depends on the accuracy of national statistical systems in each country [7].

The IEA, Eurostat and the United Nations Economic Commission for Europe (UNECE) collect data for annual energy statistics using joint questionnaires about oil, coal, gas, electricity and renewables from their member countries.

FAO maintains statistical database including information on world charcoal production at country level. The charcoal production statistics are partly collected using unofficial statistics and estimations because of the lack of official statistics in several countries. This affects the reliability of the statistics, especially because many of the largest biomass utilizing and producing countries are developing countries where reliable official statistics are frequently not available [8].

2.2 Unofficial databases and statistics

There are countless unofficial databases and statistics related to energy use maintained by various associations and organisations. The following databases and statistics have been estimated to be the most relevant for this study.

The Brazilian Sugarcane Industry Association (UNICA) [9] collects data related to the Brazilian sugarcane industry. UNICA's database includes for example the annual production data of sugarcane, ethanol and sugar production and ethanol fuel consumption data [10]. UNICA has released a publicly available list of plants producing sugarcane-based ethanol in Sao Paulo region, where 54% of the Brazilian ethanol production capacity is located. The list includes locations and capacities.

The Union of Bioenergy Producers (UDOP) is a Brazilian union that represents the producers of ethanol, sugar, bioelectricity and biodiesel. UDOP maintains a list of its members, including ethanol mills and distilleries in six states in Brazil [11]

The Renewable Fuels Association (RFA) is a national trade association for the US ethanol industry. RFA releases statistics of US ethanol production and industry but also worldwide production data. RFA maintains a list of US ethanol plants, both operating and under planning units. The list includes companies, plant locations and capacities [12].

The National Biodiesel Board (NBB) in the US maintains a publicly available list of its members. The list contains currently information of 154 biodiesel plants in the US including plant locations and also the capacity of most of the plants. NBB also releases biodiesel production statistics [13].

The Canadian Renewable Fuels Association (CRFA) maintains lists on biodiesel and ethanol plants in Canada. The list contains company names, plant locations, feedstocks and nameplate capacities [14].

The European Biodiesel Board (EBB) produces annually data on biodiesel production at country level in Europe. The statistics include also production capacity data. [15]

Reuters published in 2010 in Internet lists of European biodiesel plants and ethanol mills. The lists contain most of the plants with the capacity of at least 50 000 tons a year in Germany, France, Italy, Spain, United Kingdom, Netherlands, Poland and Hungary. Smaller plants are not listed. The lists contain company information, location, capacity and completion stage of the plants. Also plants under planning or construction at the survey time are listed. The lists are compiled through surveys of companies, producer groups and market sources [16, 17].

Bioenergy International Magazine carries out a survey of pellet plants in the world annually. The latest "World of Pellets" map was published in January 2013, and it includes company names, location and capacity of 760 pellets plants. Plants with capacities under 10 000 tons a year are excluded [18].

Ethanol Producer Magazine maintains a list and a map of ethanol plants in US and Canada with information on company, location, feedstocks and capacities. Existing plants and plants under construction are listed separately [19].

German Biofuels Industry Association (Verband der Deutschen Biokraftstoffindustrie, VBD) offers information on biofuel industry in Germany. The members of VBD combine about 80% of German biofuel capacity [20].

National Renewable Energy Laboratory (NREL) in the US maintains BioEnergy Atlas, which contains two interactive maps which include biomass feedstocks, biopower and biofuels data from the US Department of Energy (DOE), US Environmental Protection Agency (EPA) and the US Department of Agriculture (USDA). The BioFuels map includes data of biomass feedstocks and biofuels by location and also plant level information of the US biofuel plants. The BioPower map contains data of biomass feedstocks and biopower by location [21].

The National Energy Technology Laboratory in the US published in 2010 a gasification database, where world gasifiers, both coal and biomass using, are listed. In addition to the plant and company information, gasifier location, technology, feedstock, product classification and capacity are available in the list [22].

The Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) Publishes annually statistics, which contain information also of biofuels in Brazil. Annual statistics include a list of Brazilian biodiesel plants with producers, locations and capacity and production data [23, 24].

IEA Bioenergy task 32 [25] has compiled a list of plants that do or plan to do biomass co-firing. Lappeenranta University of Technology (LUT) has previously compiled a list of large recovery boilers in pulp and paper mills [26]. This list includes recovery boilers constructed since the year 1935 around the world, apart from China. Utrecht University has compiled a database of fluidized bed boilers and published an article [27] based on the database information; both have been utilised in this study.

2.3 Reports and reviews

IEA Bioenergy Task 40 country reports contain country level information on biomass usage, resources, prices and biomass import and export in Task 40 member countries. The reports have been made by each member, and the information for the reports has been collected using statistics and databases in each country. The contents vary from report to report, although in each report there is common information of biomass usage and trade in the country at issue. There are differences in the particularity and accuracy of the information. The reports of Canada, Italy, Japan and the Netherlands also provide some plant level information on biomass users. Task 40 study "*Global wood pellet industry- Market and trade study*" includes information on pellet production relevant to this study [28].

Global Agriculture Information Network (GAIN) of the United States Department of Agriculture (USDA) publishes reports on agricultural economy, products and issues in foreign countries. Information in GAIN reports is collected by the US Foreign Service officers working in more than 130 countries, but it is not official USDA data. The GAIN reports relevant to this study are Biofuels Annual Reports from countries producing large amounts of biodiesel and ethanol. The contents of the reports vary [29].

Bridgwater's [30] article presents a list of currently and recently operational industrial scale fast pyrolysis plants. IEA Bioenergy Task 40 study on torrefaction and biomass trade [31] includes examples on torrefaction plants.

National Renewable Energy Action Plans by EU member countries clarify how they plan to meet the targets of the renewable energy directive (2009/28/EC) for the year 2020. The plans are publicly available. Beurskens *et al*. at the Energy research Centre of the Netherlands (ECN) have collected data from the NREAP's to a summary report and a database [32]. This summary report focuses on the numbers and figures in the National Renewable Energy Action Plans. The textual information in the National Renewable Energy Action Plans is omitted.

Large biomass processing projects under planning and under construction have been looked for from various publicly available sources. These include for example biomass conversion related seminars, company websites and press releases, and energy related magazines.

Examples of large industrial projects utilizing biomass under planning in the EU area are found from the website of the European Commission NER300 funding programme for innovative low-carbon technologies [33]. The goal of the programme is to endow commercial scale projects of carbon capture and storage (CCS) and innovative renewable energy sources (RES) technologies.

2.4 Evaluation of data sources

The most important data sources of the study have been collected to Table 2-1. In the table, data sources have been evaluated according to their relevancy for this study. Official statistics are usually most reliable, but non-official data sources may from time to time give a needed different point of view to the studied matter.

Table 2-1 Evaluation of data sources

Data source	**The features relevant to this study**
IEA Energy Statistics	▪ Energy use information of 136 countries ▪ Classified by different biomass uses ▪ Classified by biomass type; waste, liquid, gaseous and solid biomass
National statistics	▪ More specific country level information of energy use than in international statistics ▪ Classifications and availability of information vary
Country reports by IEA bioenergy tasks and USDA	▪ Country and plant level information of bioenergy use ▪ Both history data and future estimations ▪ Information of plants, their status and feedstock use ▪ Information in the reports vary
Plant databases by associations	▪ Information of operational plants and capacities ▪ Lists of plants under construction and under planning ▪ The accuracy of the lists vary
Statistics and reports by associations	▪ Biomass use information both at continent and country level ▪ Specific data of the field of each association
Company websites and press releases	▪ Recently updated websites and latest press releases give timely information on planned projects and the status of company's facilities
Separate reports and reviews	▪ Information about the status and research of developing technologies, such as torrefaction and pyrolysis

3 DEVELOPMENT OF SOLID AND LIQUID BIOFUELS TRADE IN 2004–2011

3.1 Direct and indirect trade of biofuels

Imported biomass or a product that includes biomass can be processed in the import country into more refined final products which are then consumed within the country or exported forward. Foreign biomass that has entered the country can be used as fuel (e.g. wood pellets). Nevertheless, some products, such as ethanol or some forest industry by-products, can be used for both energy and raw material purposes, which makes it necessary to know where the products are consumed. Biomass is also traded for biofuel production, as in the case of palm oil for biodiesel, and in the future, this may be a more common trend when large biorefineries produce liquid biofuels for the transport sector. Eventually, most of the products that include biomass end up in recycling and energy production. Ethanol, vegetable oils, fuel wood, charcoal and wood pellets are the most important products that are traded internationally for energy purposes. Nevertheless, the international trade of these products is much smaller than the international trade of biomass for other purposes.

The forest industry imports wood primarily to be used as raw material. Nevertheless, during the manufacturing of the primary products, a considerable amount of the raw wood ends up in energy production or is converted into by-products that are utilised in energy production. Biofuel purchase and this kind of use is referred to in this study as indirect import of biofuels, and the corresponding export is called indirect export of biofuels. The wood streams described above jointly constitute the indirect trade of biofuels. Comprehensive information on international trade of energy biomass is important for market actors, policymakers and other stakeholders aiming to contribute to the development of biofuels markets for increasing the energy use of biomass.

Previously, the global status of direct and indirect energy biomass trade was carried out within the IEA Bioenergy task 40 during 2008–2009 by Heinimö and Junginger [2]. That study covered the years 2004–2006. Since then, some other market analyses have been published for liquid and solid biofuels [34, 35]. Those studies focused, however, on net trade of biofuels and excluded the indirect trade. In this study, the global status of solid and liquid bioenergy cross trade will be updated to cover the years 2007–2009. Furthermore, this study considers the cross streams of energy biomass trade. The aim is to find out the scale of the trade and the trend of trade figures, not to focus on the accurate country level trade figures and market analysis.

3.2 Biofuels trade volumes in 2004–2011

Figure 3-1 includes the development of indirect and direct trade of energy biomass in 2004–2011. The figures are cross trade streams. In the case of ethanol and palm oil (and other vegetable oils), the final use is not always clear, and some assumptions had to be made, as to how much of the total trade is earmarked for fuel use. The values should therefore be considered as an indicative showing the scales of various energy biomass trade streams. Still, the figure shows that while indirect trade has fluctuated between 500-680 PJ between 2004 and 2011, direct trade has more than doubled between 2004-2008, but since then also remained between 440 -500 PJ.

Currently, the scope of energy biomass trade is about 1 EJ/yr representing about 2% of the global energy use of biomass or 5% of the total use of biomass for energy in industrialised countries. Since 2004, the volume of energy biomass trade has been on the increase. Especially the direct trade of biofuels has increased strongly. The indirect trade has been quite stable during the past years. During 2008 and 2009, the indirect trade decreased due to the global economic recession. At the same time, the direct trade continued its growth. The importance of direct trade has increased remarkably. In

2004, the direct trade covered less than a fourth of the total trade. In 2011, the proportion of direct trade had increased to the same level with the indirect trade.

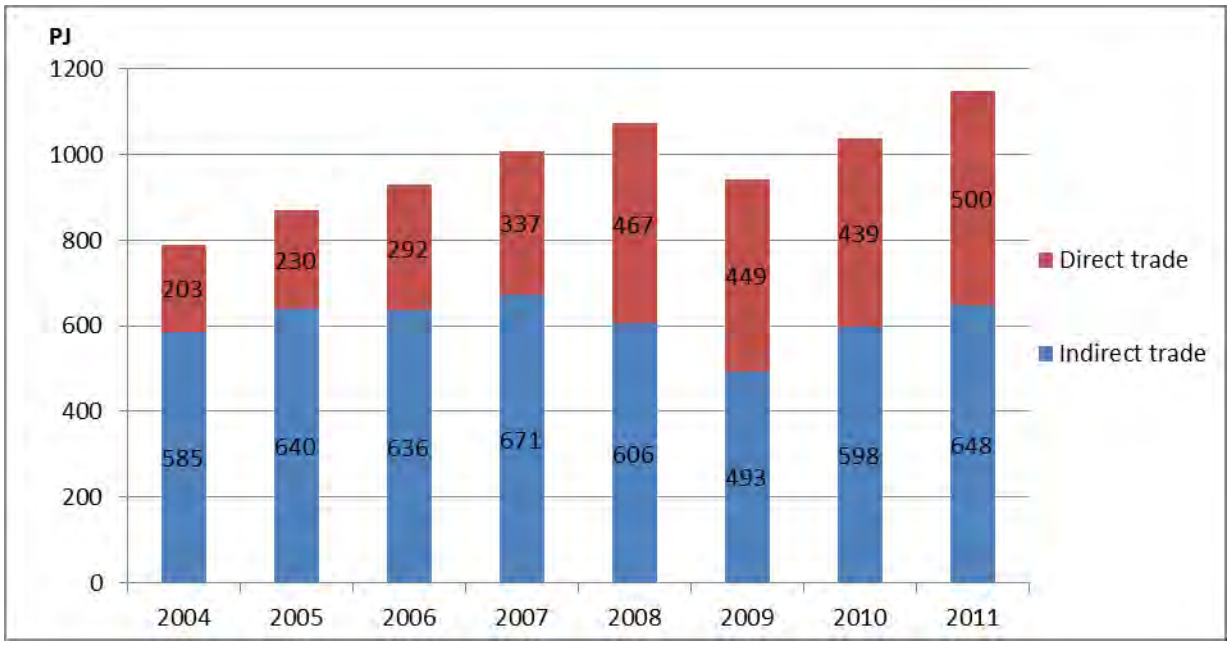

Figure 3-1 Development of direct and indirect biofuel trade in 2004–2011. *Indirect trade figures include the proportion of imported industrial round wood and wood chips that end up as energy [36].*

Figure 3-2 depicts the development of direct trade of energy biomass in 2004–2011 by various types of energy biomass. In practice, the volume of direct trade has more than doubled during the period of 2004–2011. Biodiesel has become a new important commodity in the market during that period. Also the trade volumes of wood pellets have been on the strong increase.

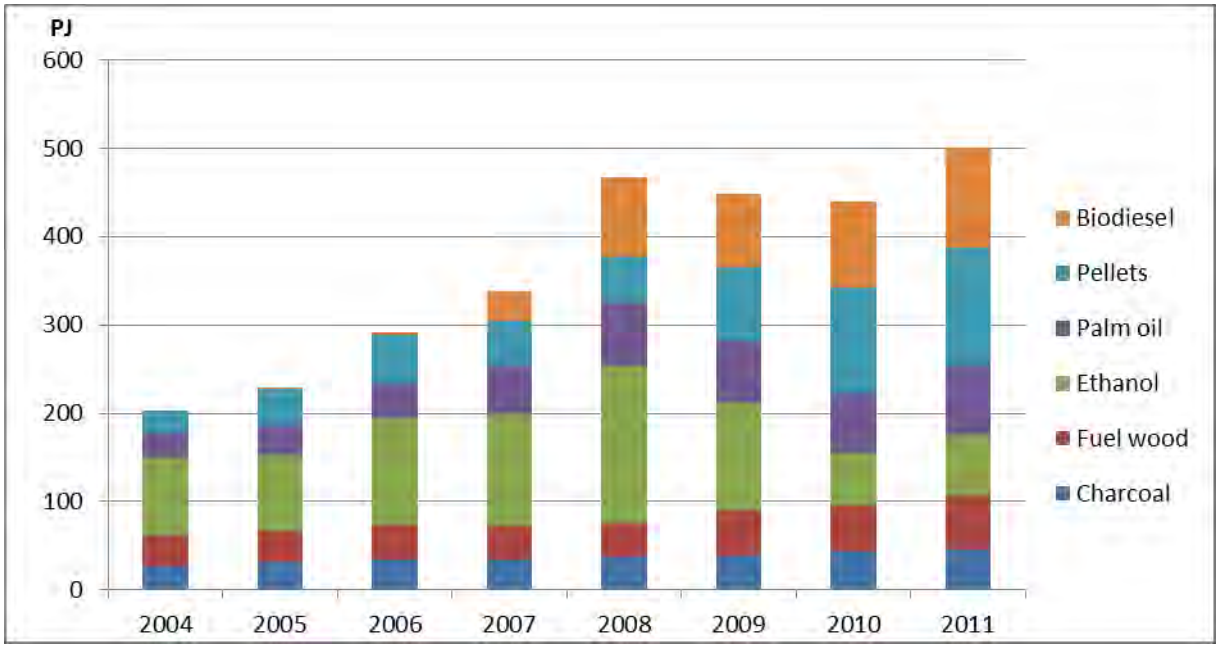

Figure 3-2 Development of direct biofuels trade by the type of biofuel in 2004–2011. *Biodiesel figures exclude intra EU-27 trade* [36].

4 MODERN ENERGY USE OF BIOMASS IN COUNTRY LEVEL

4.1 Global energy use of biomass

According to the Energy Balance of the World by IEA [1], the total use of biomass for energy was 52 EJ (as primary energy) in 2009. Figure 4-1 shows the global biomass consumption in various end-use sectors. Most of the biomass use is inefficient residential use, mainly in developing countries for cooking and heating purposes. Industry is the second largest user, followed by electricity plants and transportation sector. The modern use of biomass excludes residential and other use sectors but covers other sectors.

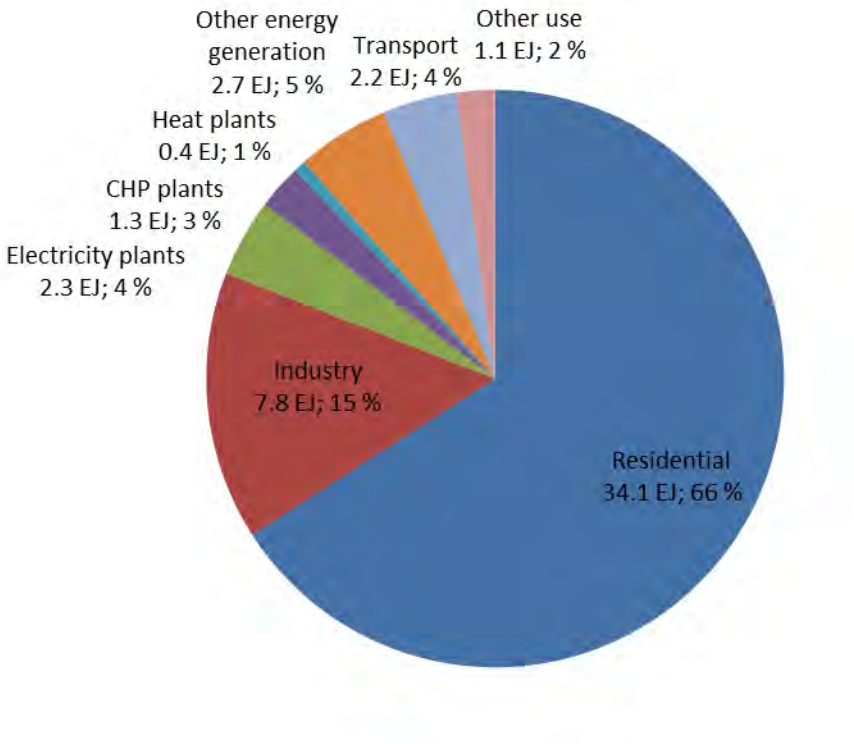

Figure 4-1 Biomass use for energy purposes in 2009. *Data obtained from the IEA* [1].

Figure 4-2 represents 15 most important biomass user countries (modern use of biomass) in industrial, transportation and power and heat production sectors in 2009. The figure shows how modern biomass use is distributed between the various sectors in these countries. The reported biomass use includes solid, liquid and gaseous biomass but excludes waste. Apart from heat and power production, energy industry use includes also its own use. In the energy industry sector the largest countries by their biomass usage are Brazil (16% of the global use in sector), US (9%) and Germany (7%). The 15 largest countries use 65% of the global use. There are several developing countries among the largest biomass user countries. Biomass use data in developing countries is typically based on outside estimates because of the lack of official internal statistics. Therefore, values reflecting the industrial usage are not necessarily accurate. For example, in Congo, Nigeria and Tanzania the biomass usage is estimated to be close to 90 % of the total energy usage. Therefore, the estimated industrial and energy use is also high.

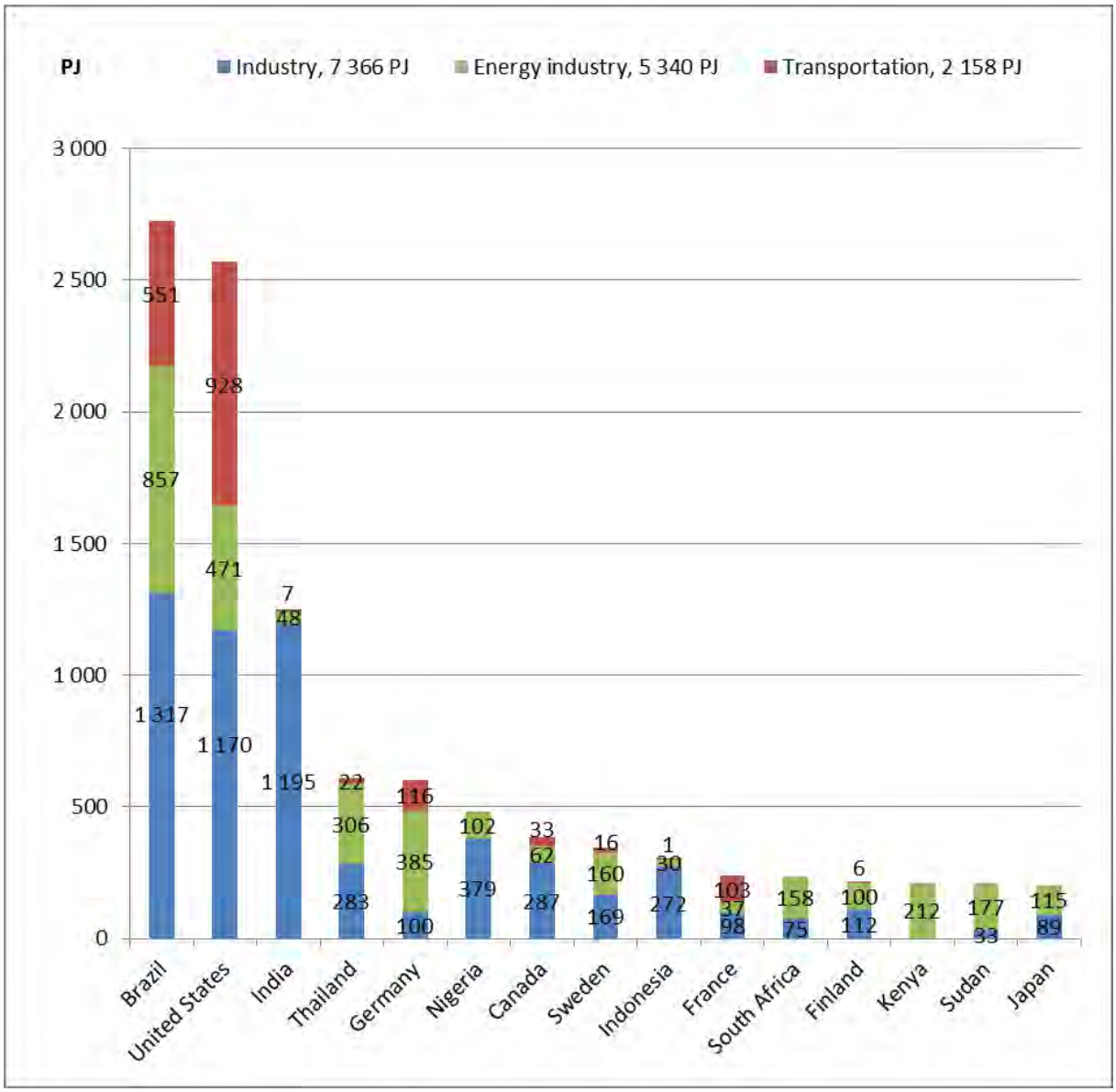

Figure 4-2 Most important biomass energy user countries in industrial, transportation and energy production sectors in 2009, and the global use of biomass per sector. In 2009, the total use of biomass in these sectors was 15 EJ, and the 15 largest user countries covered 71% of the total consumption. *Data obtained from the IEA* [1].

4.2 Biomass use in industry for energy

Countries that used most biomass for energy purposes in the industrial sector in 2009 are listed in Table **4-1**. Industrial use is mostly primary solid biomass, which is used over 7 EJ a year. Also biogases, liquids, and wastes are used, but significantly less than solid biomass. In total the countries listed use 5.9 EJ of biomass a year, which is 80% of the global biomass use in the industrial sector.

Table 4-1 The largest countries using biomass in the industrial sector in 2009 [1]

No.	Country	Liquids PJ	Biogases[1] PJ	Primary solid biomass[2] PJ	Total industrial use PJ	Share of global use
1	Brazil	0	0	1 317	1 317	18%
2	India	0	0	1 195	1 195	16%
3	United States	4	104	1 063	1 171	16%
4	Nigeria[3]	0	0	379	379	5%
5	Canada	0	0	287	287	4%
6	Thailand	0	0	283	283	4%
7	Indonesia	0	0	272	272	4%
8	Democratic Republic of Congo[3]	0	0	185	185	3%
9	Sweden	0	0	169	169	2%
10	Pakistan	0	0	135	135	2%
11	Finland	0	1	111	112	2%
12	Australia	0	0	105	105	1%
13	Germany	16	13	71	100	1%
14	France	0	1	97	98	1%
15	Japan	0	0	89	89	1%
Other countries		2	5	1 495	1 503	20%
World		22	124	7 220	7 366	100%

1) Biogases include gases from the anaerobic fermentation of biomass and thermal processes (e.g. gasification and pyrolysis) of solid biomass.
2) Primary solid biomass includes here any plant matter used directly as fuel or converted into other forms before combustion, covering e.g. charcoal and black liquor.
3) Mostly used in non-specified industry, use estimated by the IEA based on economic activity.

Biomass used in the industrial sector in India is for example bagasse, rice husk, straw and cotton stalks, which are used for power generation. Bagasse is used especially in sugar mills. Biomass is also used significantly in pulp and paper mills [37]. In Brazil, in total 21% of the energy used in the industrial sector was derived from sugar cane bagasse and 7% from other renewable primary sources in 2010. The majority of sugar cane bagasse for energy is used in the food and beverage sector, where it covers 75% of the sector energy demand [6]. The industrial sector is also the main consumer of wood based energy in Brazil, as 33% of the wood energy is charcoal used mainly in iron- and steel industry and 27% of wood used for energy goes otherwise to industrial use. Wood residues are consumed for energy purposes mainly in the pulp and paper industry, while firewood is used mainly in food and beverage sector and ceramic industry [38].

In the United States, most of the biomass used in the industrial sector is derived from forest, and more than half of this is black liquor. A third of the total industrial biomass energy use is wood and wood wastes used primarily in wood processing industry [39]. In Sweden, the industrial sector consumed 41% of the total biomass use in 2010, and 90% of this was used by pulp and paper industry. In Swedish statistics, biomass includes also waste and peat [4]. In Finland, the largest industrial energy user is the wood processing industry. In 2010, Finnish wood processing industry covered 54% of the total industrial energy use. The wood processing industry uses especially wood based biomass, which composed 45% of the total industrial energy use in 2010. In Finland, black liquor is the most important source of bioenergy in the industrial sector [3].

4.3 Biomass use in transportation sector

The largest biomass users in the transportation sector in 2009 are listed in Table 4-2. According to the IEA energy statistics, Sweden is the largest country utilising biogas in the transport sector. In other countries, biogas use in transport has been more negligible. In 2009, the global usage of liquid biofuels for transportation was 74.4 Mt equalling to 2.1 EJ, of which the 15 largest user countries consumed 95% [1]. The majority of the biofuel consumption in the transport sector takes place in the US, Brazil and in the EU-27. In the US and Brazil, ethanol is the major transport biofuel, while in the EU area, biodiesel dominates the liquid biofuel market.

Table 4-2 Biofuel consumption in the transportation sector in 2011, the largest users [1, 4-7, 40].

No.	Country	In total PJ	Gas PJ	Biodiesel PJ	Ethanol PJ	Share of global use
1	United States	917	0	55	863	43%
2	Brazil	531	0	38	494	25%
3	EU-27	498	1	381	95	23%
	Germany	124	0	107	17	6%
	France	102	0	85	17	5%
	Italy	49	0	44	5	2%
	Other EU-27	223	1	145	56	10%
4	China	52	0	11	42	2%
5	Canada	33	0	3	30	2%
6	Thailand	23	0	16	8	1%
7	Belarus	18	0	18	0	1%
Other countries		57	0	53	25	3%
World		2 131	1	574	1 557	100%

The United States consume nearly half of the global production of liquid biofuels used for transportation. Biomass based fuels account for about 2.5% of transport fuel use in the US. Ethanol is the most important biofuel in the US. In 2010, biodiesel accounted only for 2.7% of the renewable energy consumption in the US transportation sector. [39] In Brazil 2010, as much as 17.3% of the total fuel consumption in the transportation sector was alcohol, mainly ethyl alcohol but with some methanol [6]. On average, 87% of ethanol produced in Brazil is used as fuel [41].

In 2010, biodiesel covered 78% of the biofuel use in the EU-27; 21% was ethanol and ETBE and 1% other biofuels. Between 2005–2010, the annual growth of ethanol use in the EU-27 has been 40% while biodiesel use has grown 36% [32]. In 2010, the share of biofuels was 5.8% of the fuel consumption in the transportation sector in Germany. In 2007, the share of biodiesel was 72%, after which the consumption of biodiesel and vegetable oil has decreased while the consumption of ethanol has continued increasing. The most used biofuel was still biodiesel [42].

5 LARGE INDUSTRIAL PLANTS USING BIOMASS

To find out what share of the industrial biomass usage can be attributed to large industrial plants, plant lists were put together for different end use categories according to the categorisation shown in Figure 1-2. Data for plant lists was sourced mostly from various public data sources (see section 2). Due to the variable quality of data sources and large total number of biomass plants, the plant lists will include some incorrect and outdated information.

5.1 Plants that process and refine biomass to biofuels

Plants that process and refine biomass to biofuels include pellet mills, ethanol mills, biodiesel plants and other similar plants that process biomass for energy purposes. The aim was to identify the largest (TOP15) plants, their production capacity and actual yearly production (biomass utilization). For plants making charcoal from biomass, the review was done only at country level.

5.1.1 Pellet mills

In 2011, the global wood pellet production was estimated at 18.3 million tons [43], and the global production capacity is estimated to be about 35 million tons. According to these estimations, 52% of the capacity was in use. Therefore, the pellet production has a large overcapacity in the world. Most of the pellet production takes place in North America and Europe. The 15 largest pellet producer countries and their production in 2011 are shown in Table 5-1.

Table 5-1 The fifteen largest pellet producer countries in 2011 [7, 43-47].

No.	**Country**	**Production** 1000 t	**Production** PJ	**Share of global production**
1	United States	4 700	80	26%
2	Canada	1 750	30	10%
3	Germany	1 741	30	10%
4	Russia	1 590	27	9%
5	Sweden	1 288	22	7%
6	Austria	940	16	5%
7	Portugal	650	11	4%
8	Latvia	633	11	3%
9	France	550	9	3%
10	Italy	483	8	3%
11	Poland	418	7	2%
12	Estonia	360	6	2%
13	Finland	310	5	2%
14	Belgium	300	5	2%
15	United Kingdom	300	5	2%
Other countries		2 239	38	12%
World in total		18 252	310	100%

According to a survey published in Bioenergy International Magazine [18], there are globally about 600 operational pellet mills with the annual installed capacity of more than 10 000 tonnes calculated for 24/7 operation. Of these, 71 are mills with the annual installed capacity of more than 100 000 tonnes. These largest pellet mills are located in 21 countries, mainly in Northern America and Europe. Most of them are in Canada, Germany, Sweden, the US and Russia. The combined capacity of the mills listed in the survey is more than 42 million tons a year, including also mills under

construction or planned [18]. The global pellet production capacity in 2012 can be estimated to be around 40 million tons (680 PJ/a), of which the capacity of the 15 largest mills covers 14% (95 PJ/a). Table 5-2 shows these 15 largest pellet mills and their capacities. For pellet mills, there was not enough plant level data available to evaluate the actual production at mill level. Applying the above mentioned 52% utilisation rate of production capacity, the production of the 15 largest pellet mills was estimated to be about 50 PJ. More large pellet mills are listed in Appendix 1.

Table 5-2 The fifteen largest pellet mills, which together have 14% of the global pellet production capacity. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [18, 48-50]

No.	Company	Location	Country	Feedstock origin	Production	
					kt/a	PJ/a
1	Vyborgskay Cellose	Leningrad Region	Russia	L	900	15
2	Georgia Biomass (RWE)	Waycross GA	USA	L	800	14
3	Green Circle (JCE Group)	Cottondale FL	USA	L	550	9
4	Biowood[1]	Averøy	Norway	I	450	8
5	Pinnacle Pellet	Burns Lake BC	Canada	L	400	7
6	Enviva	Hertford, Ahoskie, NC	USA	?	380	6
7	Pacific BioEnergy	Prince George BC	Canada	L	360	6
8	German Pellets	Wismar	Germany	?	256	4
9	German Pellets	Herbrechtingen	Germany	?	256	4
10	Arkaim	Khabarovsk	Russia	L	250	4
11	Fram Renewable Fuels, Appling Country Pellets	Baxley, GA	USA	L	220	4
12	Pinnacle Pellet Meadowbank	Strathnaver BC	Canada	L	200	3
13	Ankit	Bengalooru	India	?	200	3
14	Hongyi Biofuels	Linyl, Shandong	China	?	200	3
15	Premium Pellet	Vanderhoof BC	Canada	L	190	3

1) Production ended in 2013

The largest pellet mills listed in the table use mainly sawdust and wood residues as feedstock. Vyborgskay Cellose mill in Russia uses chipped wood logs, and the company leased a number of forest lands in the Northwest Federal District when the plant was under construction. Feedstock is local in most of the mills listed in the table. The Biowood mill in Norway used imported wood chips from US, Canada, Liberia, Baltic region and Russia, but the production at the mill ended in 2013. The production of the largest pellet mills is mainly aimed for European markets [48]. The EU is the main destination for the wood pellet trade. European pellet production could in 2010 still cover the EU demand, but the consumption has since then been increasing faster than the production [28].

In Canada, most of the pellet production is located in British Columbia. In 2010, 72% of the pellet production capacity in Canada was utilised, and 94% of production, 1.4 million tonnes, was exported, of which 90% to Europe [51]. In the US, most of the pellet mills are small. The average capacity of a US pellet mill is between 30 000 and 70 000 tonnes per annum. Most of the mills use sawmill residue as their feedstock. Currently, the lack of suitable raw material is limiting their production [39]. Many of the new, large pellet mills do not use sawmill residue, which enables them to concentrate on export [28]. For example, the production of Georgia Biomass and Green Circle mills, 800 000 t/a and 550 000 t/a, respectively, is targeted to the European market. The Georgia Biomass mill is shown in Figure 5-1. Domestic pellet use in the US is on the rise due to government policies supporting renewable energy use, and in spite of the increasing export, 80% of the US pellet production goes to domestic use [39].

In Russia, wood pellet production is increasing; both large Russian mills listed in Table 5-2 are new mills. Most pellet mills are located in the North-West region, where transportation costs to the EU are low due to the short distance. Domestic wood pellet consumption in Russia is around 30% of the production. There are currently around 150 pellet mills in Russia, but in 2009, nine producers produced 75% of the country's total production [28].

Figure 5-1 Georgia Biomass (RWE) pellet plant in Georgia, US, produces wood pellets to be used in RWE coal-fired power plants in Europe [52].

In the European area, pellets are produced to either domestic use or for export to other European countries. Germany is the largest pellet producer in Europe with the production capacity of 3.2 million tonnes in 2010, when the actual production was 1.7 million tonnes. Nearly 70% of the production goes to domestic use, and the rest is exported to other European countries, mainly to the United Kingdom, Sweden and Denmark. In Sweden, the largest pellet producers use saw dust and shavings as raw material. The competition of raw material is intense, and pellets are consumed more than produced. In 2010, 30% of the consumption was imported. The Baltic States, Estonia, Latvia and Lithuania have good pellet production conditions due to ample forest resources and low labour and energy costs. Latvia is one of the largest pellet producers in Europe, and the production is mainly exported—the most important destinations are Denmark and Sweden. [28]

5.1.2 Ethanol mills

First generation ethanol production chains can be divided into two categories: 1) integrated ethanol, power and sugar production from sugarcane and 2) ethanol and fodder production [53]. Lignocellulosic (second generation) ethanol production technologies are still in developing phase; currently there are no large-scale commercial plants in operation.

According to the statistics of Renewable Fuels Association [12], in 2011 as much as 87% of world fuel ethanol was produced in the US and Brazil. Therefore, this study concentrates on ethanol production in these countries. Table 5-3 shows the ethanol production in 2011 by continent and the largest producer countries. In Brazil, ethanol is primarily produced using sugarcane as feedstock while in the US the feedstock is mainly corn. Based on the ethanol production capacities in the US and Brazil, it is here estimated that the global ethanol production capacity is around 109 000 Ml (2 300 PJ) per

annum. According to this estimation, the average utilisation rate of ethanol capacity was almost 80% in 2011.

Table 5-3 World fuel ethanol production in 2011 [12].

Continent	**PJ**	**Country**	**PJ**
North and Central America	1 156	United States	1 115
		Canada	37
South America	463	Brazil	447
Europe	94		
Asia	71	China	45
Australia	7		
Africa	3		
Total	1 794		

Table 5-4 shows the 15 largest ethanol mills of the world. These mills are located in the US apart from the Abengoa Bioenergy mill in the Netherlands. Brazilian mills are mainly significantly smaller than the mills in the US, as can be seen in the list of 100 largest ethanol mills in Appendix 2. The 15 largest mills are able to produce annually nearly 10 200 million litres (216 PJ) of ethanol, which is about 9% of the global production capacity. These mills use corn as feedstock apart from the Tharaldson Ethanol which uses also milo and the Abengoa Bioenergy mill which uses also wheat. There were no mill specific information available about the realised production of ethanol, and therefore, the total production of 15 largest ethanol mills was estimated to be 170 PJ. The estimation was based on the 80% capacity utilisation rate.

Table 5-4 The fifteen largest ethanol mills [12, 54].

No.	**Company/Plant**	**Location**	**Country**	**Production capacity**	
				Ml/a	PJ/a
1	Archer Daniels Midland	Columbus, NE	USA	1 136	24
2	Archer Daniels Midland	Decatur, IL	USA	1 098	23
3	Archer Daniels Midland	Cedar Rapids, IA	USA	1 041	22
4	Archer Daniels Midland	Cedar Rapids, IA	USA	908	19
5	Archer Daniels Midland	Clinton, IA	USA	897	19
6	Cargill	Blair, NE	USA	738	16
7	Aventine Renewable Energy[1]	Pekin, IL	USA	606	13
8	Tharaldson Ethanol	Casselton, ND	USA	568	12
9	Valero Renewable Fuels	Jefferson Junction, WI	USA	492	10
10	Abengoa Bioenergy	Rotterdam	Netherlands	480	10
11	Green Plains Renewable Energy	Bluffton, IN	USA	454	10
12	Green Plains Renewable Energy	Obion, TN	USA	454	10
13	Valero Renewable Fuels	Aurora, SD	USA	454	10
14	Absolute Energy	St. Ansgar, IA	USA	435	9
15	BioFuel Energy - Buffalo Lake Energy[1]	Fairmont, MN	USA	435	9

Production capacity PJ/a corresponds to the maximum possible annual production. Production PJ corresponds to the actual or calculated production in 2012.

1) Halted in September 2012 due to the lack of feedstock

In the US, there are over 200 industrial ethanol mills, and the total ethanol production capacity is about 56 000 million litres annually. The largest ethanol producer company is Archer Daniels Midland (ADM) having eight mills in the US. The combined capacity of the ADM mills is 6 510 million litres of ethanol per annum. Aventine Renewable Energy has six mills in the USA with a combined capacity of 1 741 Ml/a, two of the mills are currently operational. All the large mills use primarily corn as feedstock. [12] Ethanol imports have been decreasing since the year 2007 in the US, and exports have been minimal [39]. Since 2011 the US has however exported ethanol to especially Brazil, EU and Canada [55]. The US is the world's largest corn producer and also the largest exporter. Only small amounts of corn have been recently imported from Brazil for animal feed [56]. Therefore, it is assumed that the ethanol producers in the US use local corn.

In Brazil, there were 443 biorefineries producing ethanol in 2012. The combined capacity of Brazilian ethanol plants was about 43 billion litres annually of which Barros [41] estimates that 59% was in use. Sugarcane is the primary feedstock of ethanol in Brazil, and most of the mills are located near the sugarcane production areas. Due to the mill locations and large amounts of sugarcane produced in Brazil, it can be assumed that Brazilian ethanol is produced from local feedstock. Most of the mills produce both sugar and ethanol, varying the portion of product according to demand. According to the Ministry of Energy And Mines in Brazil [6], 83% of the total ethyl alcohol (including also methanol) produced in Brazil was consumed by the Brazilian transportation sector. Significant amounts of fuel ethanol has also been exported since 2004, mainly to the US, South Korea and Japan [38].

5.1.3 Biodiesel plants

Biodiesel is produced more in Europe than in other continents. The largest biodiesel producer countries in 2011 are listed in Table 5-5. Global Biofuels Center [57] has estimated that the biodiesel production capacity in the 25 largest producer countries is 57 billion litres equalling to 1.9 EJ. The global biodiesel capacity can be estimated to be about 2.0 EJ. In 2011, the global biodiesel production was nearly 600 PJ, which means that about one third of the production capacity was utilised.

Table 5-5 The largest biodiesel producer countries in 2011 [7, 43, 46].

No.	Country	Biodiesel production PJ	Share of global production
1	United States	120	17%
2	Germany	107	15%
3	Argentina	91	13%
4	Brazil	88	12%
5	France	68	10%
6	Indonesia	50	7%
7	Spain	25	4%
8	Italy	22	3%
9	Netherlands	18	3%
10	Portugal	14	2%
Other countries		100	14%
World in total		702	100%

In Europe, biodiesel has been mainly produced using rapeseed oil as feedstock, and in the US, the primary feedstock is soybean oil. The soybean oil share is increasing also in Europe, and also palm oil and fats are in use in Europe. In 2010, in Germany, there were 51 biodiesel plants, of which 39 were

operational. Germany both imports and exports biodiesel. Imports come mainly from the Netherlands; however, the countries of origin were mainly Argentina and Indonesia. Exports go to other European countries. [42] Biodiesel is consumed in Germany nearly as much as produced; in 2009, the consumption was 2.4 million tonnes (91 PJ) [20].

Biodiesel production in Brazil is increasing—from 2009 to 2010 the increase was 49%—and the production goes primarily to domestic consumption, 76% of it to road transport use in 2010 [6]. Biodiesel is produced mainly from soybean, but also animal fat is used. In 2011, the five largest biodiesel plants produced 34% of the country's total production [38]. The US is ranked by the Global Biofuels Center [57] to be the largest country by biodiesel production capacity in 2010. However, less than half of the capacity has been in use, although in 2011 and 2012 the production has been increasing. In 2010, only about 15% of the capacity was used, and in 2011, the utilisation rate was about 46% [58].

The fifteen largest biodiesel plants globally are listed in Table 5-6. These plants use vegetable oils, mainly palm oil and rapeseed oil as feedstock, and their capacity covers about 13% (?? PJ) of the global biodiesel production capacity. Also soybean oil, waste animal fat, sunflower oil and canola oil are used. The largest plants use typically either imported or mixed feedstock. A more extensive list of biodiesel plants can be found in Appendix 3. The total biodiesel production of the TOP15 plants was estimated to be 205 PJ. The utilisation for those plants whose actual biodiesel production figures were not available was assumed to be 80%.

Table 5-6 The fifteen largest biodiesel plants. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [13, 17, 23, 48].

No.	Company/Plant	Location	Country	Feedstock origin	Production capacity		Production
					1000 t/a	PJ/a	PJ
1	Neste Oil	Rotterdam	Netherlands	I	800	29.8	25.3
2	Neste Oil	Singapore	Singapore	I	800	29.8	25.3
3	Biopetrol	Rotterdam	Netherlands	?	650	24.2	-
4	Infinita Renovables	Castellon	Spain	M	600	22.4	-
5	Archer Daniels Midland	Hamburg	Germany	?	580	21.6	-
6	Neste Oil	Porvoo	Finland	I	525	19.6	16.6
7	Ital Green Oil	Verona	Italy	?	360	13.4	-
8	Imperium Grays Harbor	Hoquiam, WA	USA	M	333	12.4	-
9	Oleoplan	Veranópolis, RS	Brazil	L	333	12.4	7.8
10	ADM	Rondonópolis, MT	Brazil	?	303	11.3	4.9
11	Infinita Renovables	El Ferrol	Spain	M	300	11.2	-
12	Green Earth Fuels of Houston, LLC	Galena Park, TX	USA	?	300	11.2	-
13	Granol	Cachoeira do Sul, RS	Brazil	L	296	11.0	6.8
14	Louis Dreyfus Agricultural Industries	Claypool, IN	USA	L	293	10.9	-
15	Archer Daniels Midland	Velva, ND	USA	L	283	10.6	-

Capacity PJ/a corresponds to maximum possible production. Production PJ corresponds to actual or calculated production in 2012.

Neste Oil biodiesel plant in Singapore is shown in Figure 5-2. In 2011, palm oil, stearin and palm fatty acid distillate (PFAD) were the major feedstocks, which originated from Southeast Asia. Also waste animal fat from Europe, Australia and South America was used as well as small amounts of other vegetable oils from around the world [59]. Biopetrol uses rapeseed oil as feedstock. Infinita Renovables uses soya, rapeseed and palm oils from both domestic and foreign sources.

Figure 5-2 Neste Oil biodiesel plant in Singapore [59].

5.1.4 Other plants

Charcoal production

Charcoal manufacturing by carbonisation is today a very similar process to what it has been for hundreds of years, and large-scale producers or plants were not found during this study. In 2010, the global charcoal production was about 1 EJ. The largest wood charcoal producer countries in 2010 are listed in Table 5-7. The largest producer country is Brazil, where in 2010 wood charcoal was produced 6.3 million tonnes, equalling to 14% of the world total production [8]. More than 80% of it was used by the industrial sector in Brazil. In 2010, charcoal consumption formed 4.7% of the total energy consumption in the industrial sector in Brazil. Brazilian charcoal is produced from local round wood and other forest biomass [6].

Table 5-7 The largest wood-based charcoal producer countries in 2010. The production figures of Brazil, Madagascar and USA are official; others are FAO estimates [8].

No.	Country	Production	Production	Share of global
1	Brazil	6.3	139	14%
2	Nigeria	3.9	87	9%
3	Ethiopia	3.7	82	8%
4	India	2.9	63	6%
5	Democratic Republic of the Congo	2.0	45	5%
6	China	1.7	38	4%
7	United Republic of Tanzania	1.6	35	4%
8	Ghana	1.6	35	4%
9	Egypt	1.4	30	3%
10	Thailand	1.4	30	3%
11	Madagascar	1.2	26	3%
12	Zambia	1.0	23	2%
13	Colombia	1.0	23	2%
14	Sudan	1.0	23	2%
15	Somalia	1.0	21	2%
Other countries		13.2	291	29%
World in total		45.0	991	100%

Torrefaction plants

Torrefied biomass for energy production is a rather new product. During the past few years, torrefaction has been under intensive research and development worldwide. Several torrefaction plants for piloting and detailed studies have been constructed, and the first industrial-scale plants were introduced recently. The technology is likely to become commercial in the near future. The largest operational or currently commissioning torrefaction plants are listed in Table 5-8. Many torrefaction plants are not operating at the full capacity due to start-up problems. Currently, the torrefaction capacity is negligible being about 10 PJ (0.01 EJ). The actual production figures of torrefaction plants were not evaluated as the global torrefied biomass use is negligible. Existing plants use mainly wood waste, wood chips and wood residue as feedstock. The plants of which information was available use local biomass.

Table 5-8 The largest torrefaction applications. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [31, 48, 60-63].

No.	Company/Plant	Location	Country	Details	Feedstock origin	Production		Production
						1000 t/a	PJ/a	PJ/a
1	Canadian Biocoal/ Group's Vikoma	Terrace, BC	Canada	Start-up 2011	?	110	2.4	
2	Stramproy Green Investment (SGI)	Steenwijk	Netherlands	Start-up 2010	L	90	2.0	
3	New Biomass Energy	Quitman, MS	USA	Expanded 2012	L	80	1.8	
4	Topell Nederland	Duiven	Netherlands	Start-up 2011	L	60	1.3	1.0
5	LMK Energy/ Thermya	Mazingarbe	France	Commissioning	?	40	0.9	0
6	River Basin Energy	Laramie, WY	USA	Semi-commercial	?	40	0.9	
7	Torr-Coal	Dilsen-Stokkem	Netherlands	Start-up 2010	L	35	0.8	
8	ETPC	Umeå	Sweden	Start-up 2011	?	30	0.7	0.1
9	Bio Energy Development North AB	Örnsköldsvik	Sweden	Start-up 2011	?	25	0.6	
10	Idema (Grupo Lantec)	Urnieta	Spain	Start-up 2011	L	20	0.4	

Capacity (PJ/a) corresponds to maximum possible production. Production corresponds to actual or calculated production in 2012.

Torrefaction is typically combined with pelletisation to produce a denser feedstock that can be blended with coal [31]. Torrefaction is most profitable when there is a need for long haul shipments because it is a cheap method to convert biomass to a more stable and dense form. In the case of biomass trade, the logistics are one of the principal challenges. Currently, it is often profitable to use biomass only near its origin. Torrefaction carried out near the biomass origin might enable biomass transportation to become more profitable, making thus large scale plants based on imported biomass possible.

Pyrolysis oil plants

Table 5-9 Industrial scale fast pyrolysis plants currently and recently operating and their status in the end of 2012. [30, 48, 64]

No.	Company/Plant	Location	Country	Status	Production capacity		Production in 2012
					1000 t/a	PJ/a	PJ/a
1	Dynamotive	Guelph	Canada	Not in operation	67	0.76	0
2	Dynamotive	West Lorne	Canada	Not in operation	47	0.51	0
3	Ensyn	Renfrew	Canada	Operational	37	0.23	
4	Pyrovac		Canada	Demonstration plant, not in operation	34	0.33	0
5	Abritech		Canada	Not known	18	0.20	
6	BTG		Netherlands	Not in operation	17	0.19	0
7	KiOR	Columbus, MS	USA	Commissioned in 2012	50	0.09	
8	Anhui Yineng Bio-energy Ltd.		China	Not known	5	0.06	
9	Lurgi LR		Germany	Pilot plant, operational	4	0.05	
10	Metso, UPM, Fortum	Tampere	Finland	Pilot plant, project terminated	3	0.04	0

Currently, operating pyrolysis plants are mainly pilot and demonstration scale plants. Like for torrefaction, the global pyrolysis capacity is small (less than 10 PJ/a). The largest pyrolysis plants found during this study are listed in Table 5-9. Many of the plants in the list are not operating any more. Dynamotive and Ensyn have been using sawdust and wood shavings as feedstock. The actual production figures of fast pyrolysis plants were not evaluated as the global bio-oil capacity is negligible and several plants are not in operation.

Commercial scale pyrolysis plants have mainly been operated by Canadian companies. Ensyn has six small pyrolysis plants, the largest of which is located in Renfrew. The production is sold to USA, both to food and chemical markets and to be used for heating buildings. Dynamotive has had two pyrolysis oil plants in Canada, with the capacities of more than 30 000 tons a year, but these have both been shut down in 2008. Titan Clean Energy has a small plant in Canada, the objective of which is char production [51]. Metso and UPM in Finland have been developing pyrolysis technology with Fortum and the Technical Research Centre of Finland (VTT). Their pyrolyser is shown in Figure 5-3.

Pyrolysis oil density is very high compared to that of biomass, which means that the transportation cost is respectively lower. According to the calculations of Bridgwater [30], it is more recommendable to convert biomass by pyrolysis at small processing facilities at or near the biomass source than to transport it to a large scale processing facility.

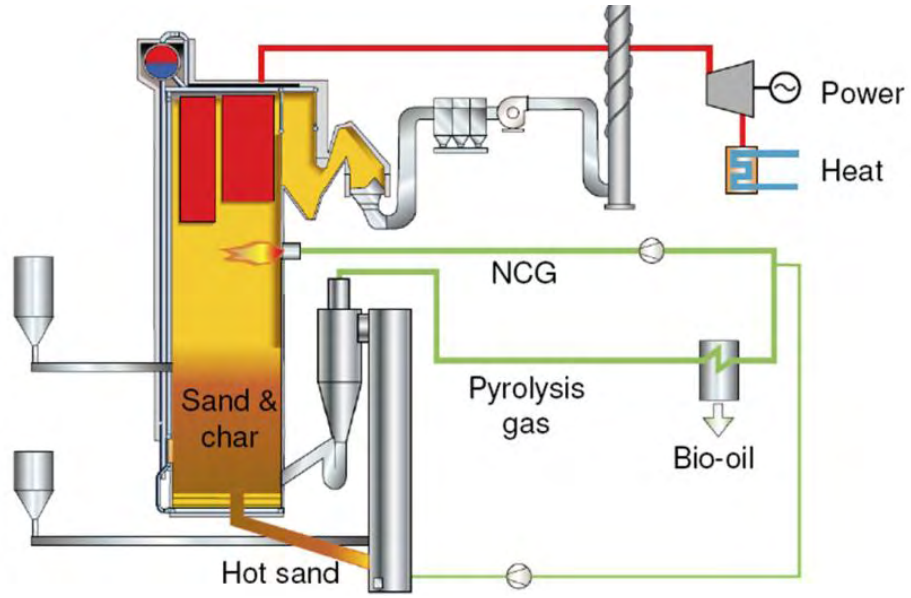

Figure 5-3. Integrated pyrolyser by VTT, Metso, UPM and Fortum [65].

5.2 Plants that convert biomass into energy

According to the IPCC estimates, about 1.3 PJ/a electricity and heat is produced from biomass, including MSW and biogas, with the average efficiency of 32%. This means that about 4.0 PJ/a of the primary energy is used [53]. IPCC further estimates that the modern biomass usage has a large carbon mitigation potential. The mitigation potential for electricity generation from biomass reaches 1,220 Mt CO_{2eq} for the year 2030; a substantial fraction of it at costs lower than USD2005 19.5/t CO_2. From a top-down assessment, the total economic mitigation potential of biomass energy supplied from agriculture is estimated to range from 70 to 1,260 Mt CO_{2eq}/a at costs of up to USD2005 19.5/t CO_{2eq}. It could extend from 560 to 2,320 Mt CO_{2eq}/a at costs of up to USD2005 48.5/t CO_{2eq}. The overall mitigation from biomass energy coming from the forest sector is estimated to reach 400 Mt CO_{2eq}/a up to 2030.

The European Climate Foundation has found that there is a large inherent cost improvement potential in biomass-generated power and heat as volumes and experiences grow—15 to 40 percent compared to the prevailing situation in 2010. Capturing these cost improvements would make biomass cost competitive with coal and gas in a broad range of applications at a carbon dioxide price of 30 to 50 EUR per ton in 2020 [66]. But they also found out that for Europe to reach its targets, a significant increase in the international biomass trade is needed.

There is a wide held belief that biomass utilization in modern boilers in combination with CCS techniques could provide a platform to ultimately result in industry sectors whose overall emissions are below zero and which could then offset the emissions in other sectors where reductions are more difficult to attain [67].

5.2.1 Recovery boilers

In 2012, 75% of the world's total wood pulp production was chemical wood pulp [68]. The chemical wood pulp production process can be divided into two major processing lines: fiber and chemical recovery. The fiber processing line extends from the wood chips cooking to the pulp bleaching section, passing by the brown pulp washing and screening steps. An aqueous solution containing NaOH and Na_2S as active compounds is used as the cooking liquor. The main goal of the fiber line is to provide conditions for the wood delignification and to achieve high brightness pulp in the end bleaching sequence.

When wood chips for pulping are produced in the mills, residues such as barks and fines are generated. In mills that particularly produce pulp, they are typically burned in auxiliary boilers to generate surplus heat. However, these residues could be better utilized if converted to alternative fuels, which would allow pulp mills to export biofuels and in turn reduce the continuous demand for fossil fuels. Furthermore, depending on the profitability of the biofuel production, additional biomass could be brought from the forest specifically for this purpose.

Pulp mills in Scandinavia and Brazil have a large potential because different types of biomass can be used as energy sources in each country. The pulp mills, for example, generate a significant amount of lignocellulosic residues. The lignocellulosic compounds represent the most significant percentage of vegetable biomass and the largest source of organic compounds in the biosphere. They contain varying amounts of cellulose, hemicellulose, lignin and a minor amount of extractives.

One of the largest brands of biomass fired boilers is the kraft recovery boiler. Kraft recovery boilers are used to burn organic residue from chemical pulp manufacture. In the world about 131 million tons of chemical pulp were produced in 2011 [8]. This corresponds to about 190 million tons of black liquor or 1.8 EJ of energy generated (not including the process energy to chemicals recovery), see Figure 1-2. They are responsible for about a quarter of all industrial biomass use in the world. Globally, there are about 630 recovery boilers in use in chemical wood pulp mills. The total biomass capacity of these boilers is about 2.70 EJ. The fifteen largest recovery boilers are depicted in

Table 5-10. They use 13% (227 PJ) of the total biomass burned in recovery boilers. An example of the modern recovery boiler is shown in Figure 5-4, that produces energy from biomass to industry as steam and electricity is Santa Fé in Nacimento Chile. The 385 MW_{th} boiler can produce 125 MW_e electricity with 111 kg/s of steam at 85 bar(a) and 485 °C.

Figure 5-4 Recovery boiler at Santa Fe, Nacimento Chile.

Table 5-10 The 15 world largest recovery boilers [26].

No.	Company/Plant	Location	Country	Feedstock origin	Production capacity		Biomass use in 2012
					tBLDS/d	PJ/a	PJ/a
1	APP Riau	Kerinchi	Indonesia	L	7 000	28.7	18.1
2	APP	Rizhao	China	L	7 000	28.7	18.1
3	Aracruz	Guaiba	Brazil	L	6 130	25.1	25.7
4	APP Hainan	Hainan	China	L	5 000	20.5	16.9
5	Suzano Papel e Celulosa	Mucuri, Bahia Sul	Brazil	L	4 700	19.2	16.9
6	Metsä-Botnia	Fray Bentos	Uruguay	L	4 450	18.2	19.2
7	Wisaforest	Pietarsaari	Finland	L	4 450	18.2	12.7
8	Celulosa Arauco y Constitución	Nueva Aldea	Chile	L	4 400	18.0	16.3
9	Veracel	Eunapolis, Bahia	Brazil	L	4 000	16.4	16.8
10	CMPC	Nacimiento	Chile	L	3 800	15.6	12.3
11	PT Riau Andalan Pulp & Paper	Kerinchi, Sumatra	Indonesia	L	3 800	15.6	12.9
12	PT Riau Andalan Pulp & Paper	RAPP 2, Kerinchi, Sumatra	Indonesia	L	3 800	15.6	10.9
13	UPM-Kymmene	Kuusankoski	Finland	L	3 600	14.8	10.7
14	Mondi	Syktyvkar	Russia	L	3 560	14.5	10.6
15	Cenibra	Ipatinga	Brazil	L	3 500	14.4	9.1

Capacity PJ/a corresponds to maximum technical black liquor use. Biomass in 2012 corresponds to actual or calculated production in 2012.

5.2.2 Biomass gasifiers

Biomass gasification is in use in a number of pilot and demonstration plants but only in a few industrial scale operational units. In 2001, Spielthoff [69] listed 35 gasification applications, most of them demo- or semi-commercial plants. During this study, 15 operating gasifiers (at least 1 MW_{th}) were found. The annual biomass gasification capacity can be estimated to be around 15 PJ. The largest operating biomass gasifiers found during this study are listed in Table 5-11. The actual biomass use in gasifiers at plant level was not evaluated as the global biomass gasification capacity is negligible. Gasifiers that use waste as feedstock have also been noticed in this list because of the small amount of operating large scale gasifiers. The ten largest gasifiers are all in quite a small area in Europe. Small facilities are in operation around the world, mainly in Europe, but also for example in the US and Japan.

The largest operational gasifiers use mainly wood-based feedstock, like forest residue, bark, waste wood and wood pellets. The status of gasification at country level depends on the background of industry and energy production in the country. In countries where gasification has been most used, there are typically widespread forest or pulp and paper industry and amply indigenous biomass. Gasifiers are currently used for co-firing purposes, for power production using gas engines and for fuel and chemicals production. There are ambitious plans for large scale (more than 100 MW_{th}) facilities for renewable diesel, ethanol and SNG production [70].

Table 5-11 The largest operational biomass gasifiers. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known). [22, 48, 71]

No.	Company/Plant	Location	Country	Feedstock origin	Production capacity		Biomass use in 2012
					MW_{fuel}	PJ/a	PJ/a
1	Lahti Energia	Lahti	Finland	L	160	4.0	2.3
2	Vaskiluodon	Vaasa	Finland	L	140	3.5	0.5
3	Rüdersdorfer Zement	Rüdersdorf	Germany	?	65	2.5	1.2
4	Essent	Geertruidenberg	Netherlands	?	55	2.1	1.5
5	Electrabel (GDF Suez)	Ruien	Belgium	?	50	1.8	1.0
6	Metsä Fibre	Joutseno	Finland	L	30	1.2	0.5
7	Södra Cell Värö Pulp Mill	Väro	Sweden	L	25	0.9	0.7
8	Agnion Technologies	Pfaffenhofen	Germany	?	20	0.8	0.2
9	Corenso United	Varkaus	Finland	M	20	0.8	0.4
10	Skive Fjernvarme	Skive	Denmark	L	20	0.8	0.6

Capacity PJ/a corresponds to maximum possible biomass use in a gasifier.

Vaskiluodon Voima Oy gasifier (Figure 5-5) in Vaasa, Finland is a 140 MW gasifier commissioned in the end of the year 2012. Vaskiluodon Voima is gasifying locally sourced forest chips, field biomass and side-products of the sawmill industry. The gas is co-fired with coal in a boiler for CHP production [72]. The gasifier facility of Lahti Energia Oy in Finland consists of two 80 MW gasifiers with gas cooler and cleaner units manufactured by Metso Oyj. Feedstock is locally sourced recovered fuel, including biomass such as wood waste. The produced gas is used in a boiler for CHP-production [73]. Metsä Fiber gasifier in Joutseno is a part of the company's pulp mill. The gasifier is currently in the testing phase, and it is scheduled to start operating in fall 2012. The gasifier is Andritz technology, and it uses locally sourced bark as feedstock. The gas is used to replace fossil fuels in the mill's lime kiln [74]. Corenso gasifier in Varkaus is developed by the Technical Research Centre of Finland (VTT) and Foster Wheeler Energia Oy, and it is used for gasifying aluminium containing reject material. The gasifier has been in operation since 2001, and it produces 50 MW gas to a boiler. Also the aluminium in the feedstock is recovered from the process for re-use [75].

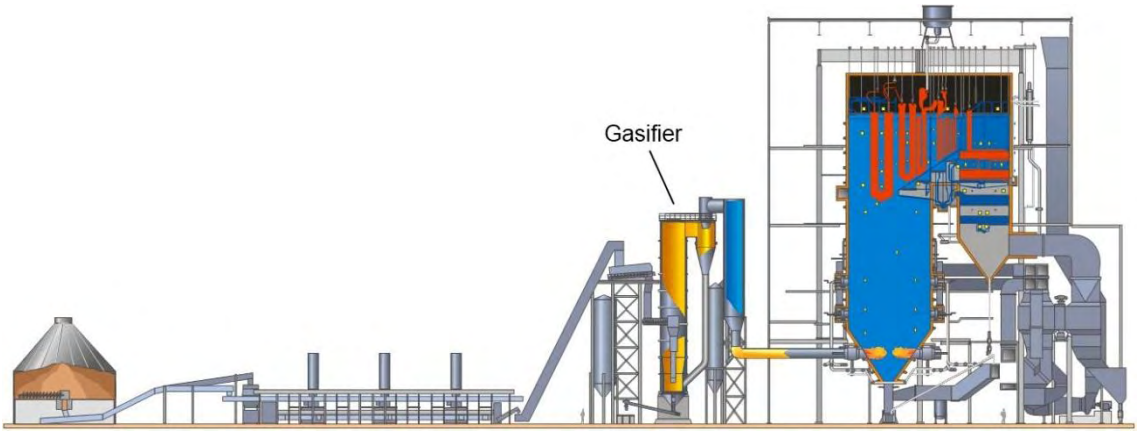

Figure 5-5 Vaskiluodon Voima biomass gasification facility. Metso Power Oy gasifier with fuel pre-treatment equipment and dryer connected to a coal-fired power plant in Vaasa, Finland was commissioned in the end of the year 2012 [72].

Gasifiers in Ulm and Villach are dual fluidized bed gasifiers, which is Austrian technology. The first dual fluidized bed gasifier application was constructed in Güssing, Austria in 2002, and it is still operating. Choren Industries Beta-plant in Freiberg, Germany is the first commercial BTL plant. The 45 MW plant was commissioned in 2009. Choren Industry has been declared bankrupt, and the plant is not operational. The Choren Carbo-V technology was in 2012 sold to Linde Engineering Dresden, who has intentions to develop it further [76]. Carbo-V process is a three-stage gasification process for syngas production.

The first biomass IGCC plant was built in Värnamo, Sweden by Sydkraft AB. The 18 MW_{th} plant operated during 1993–1999 using wood as fuel and producing electricity and heat. In 2004, the plant was acquired by Växjö Värnamo Biomass Gasification Center (VVBCG), and the objective was to upgrade the plant for syngas production. VVBCG is now looking for an industrial partnership to be able to follow through the project [77].

Coal-fired gasifiers are in use in many energy production plants around the world, also in large scale. It would be possible to co-gasify biomass in some of these gasifiers, but this is not generally done. An example is the NUON plant in Buggenum, Netherlands. It is a 235 MW_e coal-fired IGCC-plant, and it has been modified to co-gasify demolition wood with biomass input up to 30 wt-%. Biomass co-gasification has been operating since 2007 [71].

5.2.3 Co-firing in pulverized boilers

The increasing demand for larger volumes of affordable, reliable and sustainable biomass that can meet the EU sustainability criteria is growing [78]. There are regions where biomass is widely available and relatively cheap, such as Russia, Belarus, Ukraine, Slovakia, Brazil, Africa, Canada and the US. Therefore, importing biomass to Europe to help it to fulfil the renewable quote would be possible. There are financing hurdles and a tendency to wait and see. The investments in thermally treated biomass are limited, but significant investments in wood pellet plants are happening.

In the EU, there are tough conditions for biomass co-firing in many countries, and it has not yet started up. This means that the investors suffer from uncertainties. One of the reasons is that the renewability of biomass is not undisputed for political reasons. However, co-firing it in existing power plants would be feasible, especially as it is proven technology and in existing power plants, high thermal efficiencies can be achieved. "*Co-firing and full scale coal to biomass conversion could be a solution to meet short term renewable targets in both EU and US*" [78].

According to IEA Task 32 database [25], there were globally about 110 plants able to co-fire biomass in pulverized firing boilers in 2009. The global co-firing capacity can be estimated to be about 400 PJ/a. The fifteen largest pulverized firing boilers (PF) that co-fire biomass (Table 5-12) have the total capacity of 171 PJ of biomass usage per year. The actual biomass usage in pulverized fired-boilers in 2011 was estimated to be about half (200 PJ) of the total capacity as many operations were still in the start-up phase. The actual biomass use of the TOP15 biomass co-firing plants was using the same criteria assumed to be about 55 PJ.

Table 5-12 The fifteen largest pulverized firing boilers that co-fire biomass based on their biomass consumption capacity usage. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [25, 48].

No.	Company/Plant	Location	Country	Total Power output MW_e	Biomass origin	Production capacity (bio) MW_{fuel}(bio)	PJ/a
1	Electrabel	Rodenhuize	Belgium	180	I	840	21.2
2	RWEnpower	Oxfordshire	UK	2100	I	656	16.5
3	Drax Power	North Yorkshire	UK	4000	I	625	15.8
4	DONG Energy	Copenhagen	Denmark	365	I	592	14.9
5	RWE Essent	Geertruidenberg	Netherlands	600	I	577	14.5
6	British Energy	Yorkshire	UK	1960	I	460	11.6
7	Electrabel	Liège	Belgium	80	I	420	10.6
8	Scottish Power	Scotland	UK	2400	M	375	9.5
9	Vattenfall	Copenhagen	Denmark	80	I	330	8.3
10	SSE	Yorkshire	UK	2035	I	327	8.2
11	E.ON	Kent	UK	2034	I	318	8.0
12	E.ON	Nottinghamshire	UK	2010	I	314	7.9
13	EDF Energy	Nottinghamshire	UK	2000	I	313	7.9
14	SSE	Lancashire	UK	1995	I	312	7.9
15	EDF Energy	Nottinghamshire	UK	1980	I	309	7.8

MWfuel(bio) corresponds to the maximum tehnical capacity of primary biomass feed into the boiler. Capacity PJ/a corresponds to maximum possible biomass usage.

5.2.4 Combined heat and power production with biomass in industry and CHP

Fluidized bed boilers (Figure 5-6) are common in heat and power production from biomass due to their fuel flexibility. Large boilers (more than 200 MW_{th}) used typically for utility power production are typically circulating fluidised bed (CFB) boilers. These are discussed in more detail in section 5.2.5. Bubbling fluidized bed (BFB) boilers are smaller but commonly used in industry and CHP production.

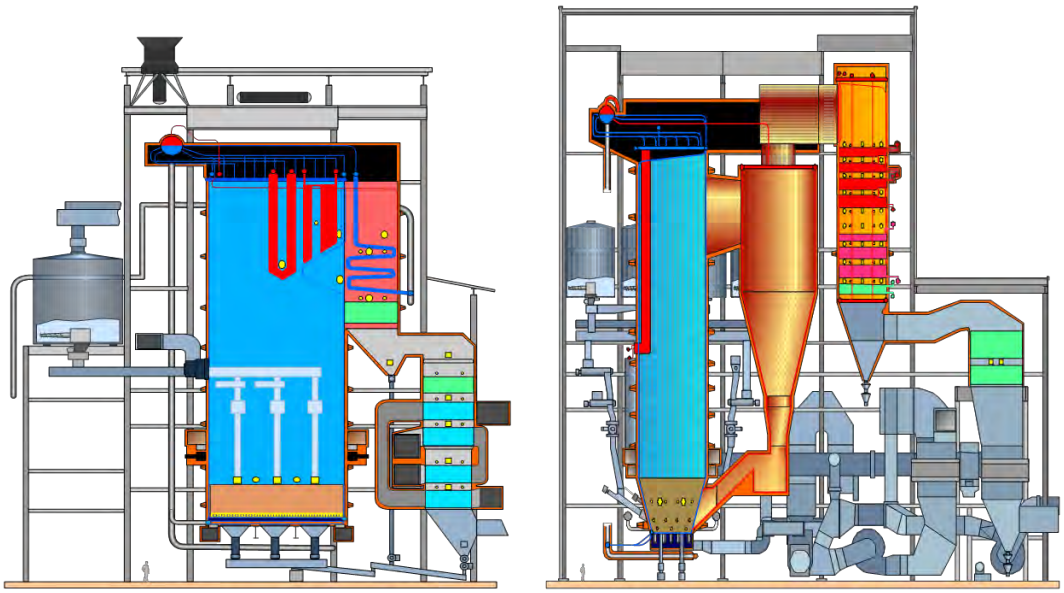

Figure 5-6 Fluidized bed boilers; bubbling fluidized bed (BFB) on the left and Circulating fluidized bed (CFB) on the right.

Biomass for energy generation has been commonly defined as virgin wood, energy crops, agricultural residues, solid wastes and industrial co-products. It is predominantly used as the largest energy source for fuel in the share of bioenergy within renewables, since there are not much limited requirements for its store, transportation, load and applications at the location and time of energy consumption [79].

Especially important for the development of biomass utilization in large scale has been the development and introduction of fluidized bed boilers which are very suitable to fire various biomasses. A lot of progress has been made in understanding the role of certain harmful elements in biomass. These include chlorine, potassium, sulfur, nitrogen and silicon. Especially alkali and chlorine, which are found in high quantities in certain biomass types, such as straw but also in hardwoods, affect biomass boiler operation by causing corrosion [80]. The second problem is the agglomeration and related problems in the bed material, which can be solved with proper operation [81]. It is the circulating fluidized beds (CFB) that have achieved the largest sizes, but much larger fraction of bubbling fluidized bed (BFB) boilers is currently burning biomasses [27, 82, 83].

Koornneef *et al*. [27] have analyzed fluidized bed boiler markets and found that there is still room for both technical and economic improvement. They found a progress ratio of about 0.90 for the fluidized bed boiler market. This means that the specific investment prices (in €/kW_e) decline with 10% with every doubling of cumulative installed capacity (in MW_e). An example of large fluidized bed boilers that produce energy from biomass as electricity and heat to industry as steam is the DALKIA Facture biomass boiler. The 124 MW_{th} boiler can produce 29 MW_e electricity with 47 kg/s of steam at 119 bar(a) and 520 °C while burning bark, sawdust, wood chips, sludge, forest residue and recycled wood, Figure 5-7.

Figure 5-7 Dalkia Facture biomass power plant, France (foto: Metso Power).

As mentioned above, most of the biomass utilised in fluidized boilers in industry and CHP are burned in BFB type of boilers. Most of the plants use both biomass and fossil fuels. The 15 largest BFB boilers that fire biomass are listed in Table 5-13. This list includes BFB boilers that are known to fire biomass. Boilers that fire only for example coal are excluded. Peat firing has not been included into the biomass capacity. The largest non-biomass BFB TVA Paducah, KY, USA boiler at 305 MW_{th} was idled at 2011. In the next section, CFB boilers are looked at in more detail.

Table 5-13 The fifteen largest Bubbling fluidized bed boilers that fire biomass (BFB) Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known). [27] [Vendor data]. *Total biomass usage capacity of the TOP 15 plants is about 60 PJ and estimated biomass use about 42 PJ.*

No.	Company/Plant	Location	Country	Biomass origin	Production capacity (bio)		Biomass in 2012
					MW_{fuel}(bio)	PJ/a	PJ/a
1	Southern Power	Nacogdoches	USA	L	292	6.6	5.4
2	Fortum	Uimaharju	Finland	L	235	5.3	2.7
3	Kymin Voima	Kuusankoski	Finland	L	188	4.1	2.3
4	Zespół Elektrowni Dolna Odra	Szczecin	Poland	L	183	4.6	4.0
5	Fortum	Joensuu	Finland	L	180	4.5	3.4
6	Bomhus Energi	Gävle	Sweden	L	170	4.3	3.7
7	Segezha Pulp&Paper Mill	Sezezha	Russia	L	165	4.2	3.0
8	Iggesund Paperboard	Workington	Great Britain	L	135	3.4	1.5
9	Grupo Ence	Huelva	Spain	L	135	3.4	3.0
10	P.T. Wirakarya Sakti	Jambi	Indonesia	L	131	3.3	2.3
11	Övik Energi,	Örnsköldsvik	Sweden	L	130	3.3	3.0
12	Dalkia Łódź	Łódź	Poland	L	125	3.2	1.5
13	Dalkia France SCA	Facture	France	L	124	3.1	0.9
14	Rauma Paper	Rauma	Finland	L	124	3.1	2.1
15	Arauco	Cholguan	Chile	L	123	3.1	2.7

Capacity PJ/a corresponds to maximum possible annual biomass usage.

Koornneef *et al*. [27] and Hupa [82] have studied the BFB boiler markets. The total BFB boiler capacity in 2011 was 24 000 MW_{th}. It will increase by 10 000 MW_{th} from 2010 to 2020. They also estimate that about 72% of the fuel usage is biomass. This would mean that the current biomass use in BFB plants is 435 PJ and would increase by 181 PJ by 2020. Currently, there are approximately 600 biomass fired BFB-boilers globally. The total biomass consumption capacity in these boilers is estimated to be 540 PJ. The fifteen largest biomass power plants with BFB technology consumed about 42 PJ of biomass in 2010 which represents about 10% of the biomass use of BFB boilers worldwide.

5.2.5 Utility power production with biomass

Biofuel firing for power generation has been marginal. As biomass boilers were small, fuel procurement chains non-existent and relative fuel price high, the utilities tended to ignore biomass usage [84]. Now with the international drive to decrease CO_2 carbon dioxide emissions, the biomass has become a more interesting fuel for power generating utilities and the market for utility biomass boilers has intensified. Utility boilers tend to be large, and therefore the CFB boiler technology is preferred.

An example of large circulating fluidized bed boilers that produce energy from biomass to both industry as steam and community as district heat and electricity is Kaukaan Voima (Figure 5-8) in Lappeenranta, Finland. The 385 MW_{th} boiler can produce 125 MW_e electricity with 149 kg/s of steam at 115 bar(a) and 550°C.

Figure 5-8 Kaukaan Voima in Lappeenranta Finland

Koornneef *et al*. [27] and Hupa [82] have studied CFB boiler markets. Based on their data, the CFB boiler capacity in 2011 was 122 000 MW_{th}. It will increase by 65 000 MW_{th} from 2010 to 2020. They also estimate that about 11% of the fuel usage is biomass. This would mean that the current biomass usage is 240 PJ and would increase by 130 PJ by 2020. Currently, there are approximately 250 CFB boilers that use biomass globally. The total biomass consumption capacity of CFB boilers is estimated to be 300 PJ. The 15 largest biomass power plants with CFB technology are depicted in Table 5-14. These plants use about 55 PJ of biomass which represents more than 20% of the biomass use in CFB boilers. There are also many plants using a mix of biomass and fossil fuels; for example Alholmens Kraft uses a mixture of coal and biomasses.

Table 5-14 The 15 largest circulating fluidized bed boilers (CFB) Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [27] [Vendor data].

No.	Company/Plant	Location	Country	Biomass origin	Capacity (bio)		Biomass in 2012
					MW_{th}(bio)	PJ/a	PJ
1	GDF Suez	Polaniec	Poland	L	556	10.0	8.0
2	Kaukaan Voima	Lappeenranta	Finland	L	400	5.7	5.8
3	Alhomens Kraft	Pietarsaari	Finland	M	550	7.9	5.5
4	Guangdong Yudean	Zhanjiang	China	L	2*155	5.2	5.2
5	Stora Enso	Ostroleka	Poland	L	164	2.4	3.6
6	Söderenergi	Södertälje	Sweden	L	240	3.5	3.5
7	Indah Kiat P& P	Peravang	Indonesia	L	171	2.5	3.5
8	Rhein energie	Köln	Germany	L	236	3.4	3.4
9	Shaw	Virginia	USA	L	200	2.9	2.9
10	Klabin		Brazil	L	197	2.8	2.8
11	EC Tychy	Tychy	Poland	L	184	2.7	2.7
12	Oulun energia	Oulu	Finland	M	315	4.5	2.6
13	ZE PAK	Konin	Poland	L	157	2.3	2.3
14	Stora Enso	Maxau	Germany	L	156	2.3	1.7
15	Jyväskylän Energia	Jyväskylä	Finland	L	597	2.6	1.6

Capacity PJ/a(max) corresponds to the maximum possible biomass usage, Biomass in 2012 PJ/a corresponds to the actual or calculated biomass usage in 2012.

6 IDENTIFICATION OF BIOFUEL AND BIOENERGY PROJECTS UNDER PLANNING

6.1 Plants that refine or process biomass to biofuels

6.1.1 Pellet mills

Large pellets mills are under planning especially in the US and Canada. The mills are located in areas where woody biomass is plentifully available, and the pellets are mostly aimed for export to Europebut also to Asia. The largest pellet mill projects found during this study are listed in Table 6-1. The list reflects the state at the end of the year 2012, and it is not comprehensive. There were 41 pellet mills found (capacity at least 1PJ/a) under planning with the total capacity of around 243 PJ/a.

Suzano Energia Renovavel is planning to construct three wood pellet mills in Brazil by year 2014; the annual capacity of each would be one million tons [85]. Suzano is also planning to build two more mills in year 2018 or 2019. The production of the mills is destined for European markets. The listed facility of Biomass Secure Power (BSP) planned to be constructed in the US is intended for the production of white pellets, but the company is also planning a second phase, which would mean building a production line for 340 000 tonnes a year of torrefied pellets. There are also other plans for the production of torrefied pellets. Zilkha Biomass Fuels intends to produce black pellets similar to torrefied pellets in Selma, Alabama, US. The facility with the capacity of 275 000 tonnes a year (4.7 PJ/a) is under construction and is to be operational in 2013 [86]. Miktech Oy in Finland is planning a torrefied pellet mill with the capacity of 200 000 tonnes a year (3.4 PJ) [87].

Table 6-1 The largest wood pellet mill projects under planning or under construction at the end of 2012. Not a comprehensive list. [28, 48, 49, 85]

No.	Company/Project	Location	Country	Feedstock origin	Production capacity	
					1000 t/a	PJ/a
1	Suzano Energia Renovavel [1]	Maranhão	Brazil		1 000	17.0
2	Biomass Secure Power	Baton Rouge, LA	USA		1 000	17.0
3	German Pellets	Tyler, TX	USA	L	550	9.4
4	Protocol Biomass	Ontario	Canada		500	8.5
5	Fram Renewable Fuels	Hazlehurst, GA	USA		500	8.5
6	Franklin Pellets	Franklin, VA	USA		500	8.5
7	Enviva LP	Courtland, Southampton, VA	USA	L	500	8.5
8	Enviva LP	Northampton County, NC	USA		500	8.5
9	Enviva LP	Wiggins, MS	USA		500	8.5
10	Enova Energy Group	Edgefield County, SC	USA		450	7.7
11	Enova Energy Group (First [illegible])	Waynesville, GA	USA		450	7.7
12	Enova Energy Group	Warrenton, GA	USA		450	7.7
13	Canadian Bio Pellets	Ingleside	Canada		450	7.7
14	General Biofuels Georgia	Sandersville, GA	USA	L	440	7.5
15	Point Bio Energy	Baton Rouge, LA	USA		400	6.8

1) Project abandoned in 2013

6.1.2 Ethanol mills

The largest ethanol production projects currently under planning or under construction are listed in Table 6-2. During the study, 23 ethanol mills (capacity at least 1 PJ/a) under planning were found; the

ttotal capacity of the mills was about 80 PJ/a. The list reflects the state at the end of the year 2012, and it is not comprehensive. The Brazilian Government is going to support small start-up ethanol producers and thus promote ethanol industry by decentralising [88]. These small units will be allowed to sell ethanol directly to customers, and therefore, this is not likely to affect the ethanol exports from Brazil. The investments on new ethanol mills in Brazil have been decreasing recently, and at the same time, ethanol imports from the US have been increasing [9, 24].

Table 6-2 The largest ethanol mills under planning or under construction at the end of 2012. Not a comprehensive list. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known). [19, 48]

No.	Company/Project	Location	Country	Feedstock	Feedstock origin	Production capacity	
						Ml/a	PJ/a
1	Poet	Emmetsburg, IA	USA	Corn fiber, cobs, stalks	?	473	10.0
2	Montana Advanced Biofuel	Great Falls, MT	USA	Wheat, barley	?	435	9.2
3	Vivergo Fuels	Hull	United Kingdom	Wheat	L	420	8.9
4	Coskata	undisclosed	USA		?	379	8.0
5	Bioethanol	North Killingholme	United Kingdom	Corn	L	250	5.3
6	Vireol	Grimsby	United Kingdom	Wheat/other grains	L	200	4.2
7	GeneSyst U.K.		Malta	Non-food biomass	I	180	3.8
8	Mascoma	Kinross, MI	USA	Woody biomass	?	151	3.2
9	BP Biofuels	Highlands County, FL	USA	Energy grass	?	136	2.9
10	Canabrava	Rio de Janeiro	Brazil	Sugarcane	L	120	2.5
11	Verenium		USA		?	114	2.4
12	Abengoa		Brazil	Sugar cane straw and bagasse	?	100	2.1
13	Abengoa Bioenergy	Hugoton, KS	USA	Agricultural residues, switchgrass	?	95	2.0
14	Poet	Emmetsburg, IA	USA	Corn cob	?	95	2.0
15	Louisiana Green Fuels	Lacassine, LA	USA	Sugarcane bagasse	L	95	2.0

6.1.3 Biodiesel plants

Biodiesel production projects under planning are listed in Table 6-3. The list reflects the state at the end of the year 2012, and it is not comprehensive. During this study, 24 biodiesel projects under planning were found; the total capacity of these was 633 PJ, most of this in Indian projects. By 2017, the Indian government aims to achieve the 20% blending rate of biodiesel in diesel fuel. The aim is followed by the target of planting 11.2 to 13.4 million hectares of land by jatropha by 2012 for biodiesel production. At present, the blending target seems unattainable because of the lack of feedstock for biodiesel production; also most of the biodiesel units are not operational most of the year. [37] Indian Railways is planning to construct two large biodiesel plants to be commissioned in 2013, and two other plants are also under planning.

Table 6-3 The largest biodiesel projects under planning or under construction at the end of 2012. Not a comprehensive list. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [14, 48].

No.	Company/Project	Location	Country	Feedstock	Feedstock origin	Status	Production capacity	
							1000 t/a	PJ/a
1	Indian Railways	Tondiarpet	India	Not known	?	P	257 163	257
2	Indian Railways	Raipur	India	Not known	?	P	257 163	257
3	Brasil Eco Energia		Brazil	Soybeans	?	P	27 373	27.4
4	Biodiesel of Las Vegas	Las Vegas, NV	USA	Multi-feedstock	?	U	12 414	12.4
5	Canadian Bioenergy - Northern Biodiesel	Lloydminster, AB	Canada	Canola	?	P	8 691	8.7
6	ADM	Lloydminster, AB	Canada	Canola	?	U	8 690	8.7
7	BioStreet Canada	Vegreville, AB	Canada	Oilseed	?	P	7 773	7.8
8	REG New Orleans	St. Rose, LA	USA	Multi-feedstock	?	U	7 572	7.6
9	REG Emporia	Emporia, KS	USA	Multi-feedstock	?	U	7 448	7.4
10	Great Lakes Biodiesel	Welland, Ontario	Canada	Multi-feedstock	?	U	5 591	5.6
11	Bioversel Sarnia	Sarnia, Ontario	Canada	Multi-feedstock	?	P	5 576	5.6
12	Four Rivers Bioenergy	Wilton	United Kingdom	Used cooking oil, virgin soy and rapeseed oil	?	U	4 472	4.5
13	BIOX	Bayonne	Canada	Waste grease and oil	?	PP	3 280	3.3
14	TRT-ETGO	Bécancour, Quebec	Canada	Vegetable oil	?	P	3 280	3.3
15	Viridis Fuels	Oakland, CA	USA	Used vegetable and animal fats	L	P	2 483	2.5

A few renewable diesel production projects were also found during the study. UPM is constructing a renewable diesel production facility with the capacity of 100 000 tonnes a year (3.7 PJ) in Lappeenranta, Finland. The plant will use local crude tall oil as feedstock, and it is planned to be operational in 2014. UPM is also planning a BTL-plant which would be located either in Rauma, Finland or Strasbourg, France. The plant capacity would be about the same as in Lappeenranta, and it would produce renewable diesel from woody biomass. Vapo is planning to construct a BTL-plant in Kemi, Finland. The plant would be producing 100 000 tonnes a year (3.7 PJ) renewable diesel from wood-based raw material. [48]

6.1.4 Other projects

There are a few commercial scale fast pyrolysis plants currently under planning. These have been listed in Table 6-4. The list reflects the state at the end of the year 2012, and it is not comprehensive. The listed plants are planned to be using woody biomass as feedstock, for example forest residue, sawmill residue or wood waste. Fortum fast pyrolysis plant is to be built next to the existing CHP-plant in Joensuu, Finland, and it is planned to be operational by the end of 2013. Figure 6-1 shows the process of the plant.

Table 6-4 Commercial scale fast pyrolysis plants under planning or consideration. The list is not comprehensive. [48, 64]

No.	Company/Project	Location	Country	Capacity PJ/a
1	Pyrogrot	Skärblacka	Sweden	2.8
2	KiOR	Natchez, MS	USA	2.6
3	Green Fuel Nordic	Savonlinna/Iisalmi	Finland	1.9
4	High North BioResources	High Level, Alberta	Canada	1.6
5	Fortum	Joensuu	Finland	0.9
6	Renewable Oil Corporation (ROC)		Australia	0.8

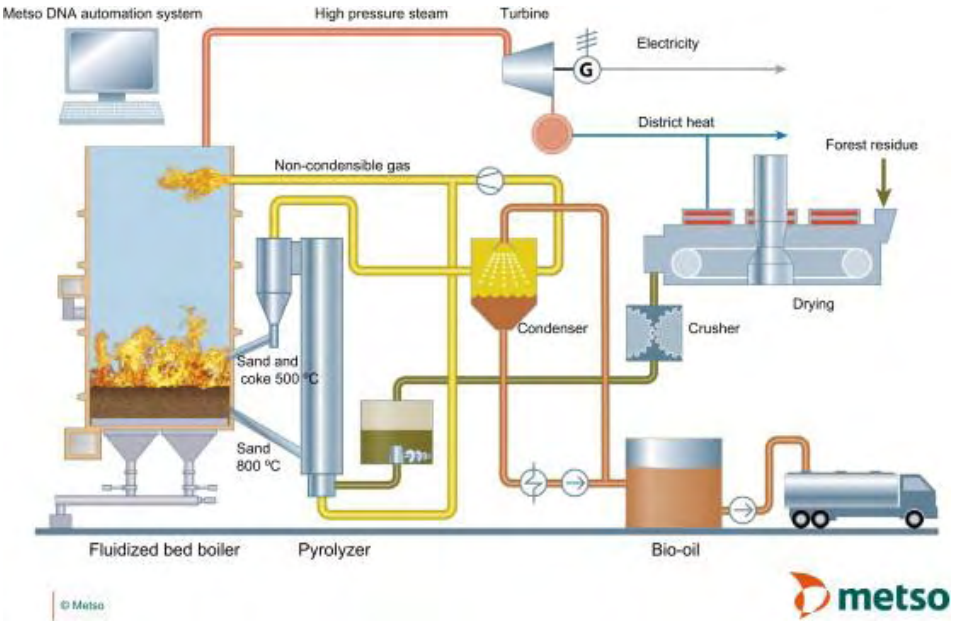

Figure 6-1 Fortum's fast pyrolysis plant for bio-oil production to be built in Joensuu, Finland.

Industrial scale torrefaction plants are planned in Canada and Netherlands. Global Bio-Coal Energy in British Columbia, Canada has an intention to construct a plant with the capacity of 300 000 t/a (6.6 PJ/a). In the Netherlands, Fox Coal is planning a plant with the annual capacity of 96 000 t/a (2.1 PJ/a). [48]

6.2 Plants that convert biomass into energy

6.2.1 Recovery boilers

Pulp mill construction activity has sifted to South-America and Asia. In Europe, the printing paper production declines and overcapacity is evident.

Table 6-5 Recovery boiler projects planned (P) or under construction (U). [26]

No.	Company/Project	Location	Country	tBLds/d	Status	Capacity PJ/a
1	Suzano	Maranhaõ	Brazil	7000	U	28.7
2	Eldorado	Três Lagoas	Brazil	6800	U	26.8
3	Montes del Plata	Montes del Plata	Uruguay	5710	U	23.4
4	Fibria	Três Lagoas	Brazil	5300	U	21.7
5	CMPC Celulose Riograndense	Guaiba	Brazil	5000	U	20.3
6	Stora Enso	Beihai	China	4000	U	18.1
7	Asia Pulp and Paper	Kalimantan	Indonesia	8000	P	30.8
8	Suzano	Piauí	Brazil	7000	P	28.5
9	Ilim Group	Bratsk	Russia	4500	P	17.2
10	Angara Paper	Eniseyskiy	Russia	4000	P	15.4

6.2.2 Biomass gasifiers

The largest gasifier projects planned or under construction are listed in Table 6-6. These gasifiers use mainly woody biomass, such as forest residue as feedstock. Feedstock origin is not known.

Table 6-6 Gasifier projects planned (P) or under construction (U). [22, 33, 48, 64]

No.	Company/Project	Location	Country	Products	Status	Capacity PJ/a
1	E.ON Bio2G	Landskrona	Sweden	SNG	P	5.0
2	Sundrop Fuels	Alexandria, LA	USA	Renewable gasoline	U	4.0
3	GoBiGas phase 2	Gothenburg	Sweden	SNG	P	2.5
4	OMV	Vienna	Austria	Hydrogen	P	1.3
5	BTL-project, owner confidential		France	Liquid fuels	P	0.6
6	Wärmeversorgung Großenhain / POW	Großenhain/ Naundorf	Germany	CHP	P	0.5
7	Göteborg Energi, GoBiGas	Göteborg	Sweden	Gaseous fuels, SNG	U	0.5
8	VERBIO Straw	Schwedt	Germany	Methane	P	0.5
9	H2Herten GmbH	Herten	Germany	Power, H2	U	0.3
10	KIT Karlsruhe Institut of Technology	Karlsruhe	Germany	Liquid fuels, BTL	U	0.1

6.2.3 Other biomass projects

In addition to the existing biomass boilers/utilities, there is a set of projects currently planned which will further expand the biomass usage in the world. Some of them are building new biomass plants, whereas many other projects consist of converting totally or partially a previous fossil fuel burning into biomass firing.

For instance, Drax power station case in Great Britain should be commented. Currently, it consists of six units of 660 MWe each, burning coal with maybe a small share (12,5%) of biomass co-combustion. It is the largest power station in Europe [89]. Measures and projects are being carried out to convert three of its units to biomass-firing from 2013 to 2017. Moreover, a new additional

300 MWe unit which will burn biomass is also under planning to start working on 2017 [90, 91]. This all means yields into a consumption of 142PJ per year from the final delivery.

Also, Samcheok (Korea) power station project should be mentioned due to its size. According to the planner Foster Wheeler, when this project will be finished, the power station will combine several renewable energy sources up to the total capacity of 5 GWe. It will have 8 co-fired (coal and biomass) supercritical CFB boilers producing a power of 550 MWe. [92, 93]. The estimation of biomass usage is almost 105PJ per year.

Other data and estimation related to other biomass-burning projects can be found in the following table.

Table 6-7 The largest biomass boiler projects under planning or under construction. Feedstock origin: L (Local), I (Import), M (Mixed), ? (Not known) [84, 89-100].

No.	Company/Project	Location	Country	MW_{th} (bio)	Year of delivery	Capacity PJ/a	Burning technology
1	Drax Group	Drax	UK	6000	2017	141.9	CFB
2	KOSPO	Samcheok	South Korea	4400	2015	104.1	CFB
3	Eggborough Power	Eggborough	UK	2000	2014	47.3	CFB
4	International Power/Rugeley	Staffordshire	UK	1026	ca 2015	26.1	CFB
5	Dong	Hull	UK	857	2015	20.3	CFB
6	MGT	Teesport	UK	789	2016	18.7	CFB
7	MGT Power	Teeside	UK	750	2015	17.7	CFB
8	OPG	Ontario	Canada	625	2014	14.8	
9	KoEslöv Lund Kraftvärmeverk	Örtofta, Lund	Sweden	500	2015	11.8	CFB
10	We Energies	Rothschild, Wisconsin	USA	293	2013	6.9	CFB
11	Gainesville Renewable Energy Center	Gainesville, Florida	USA	286	late 2013	8.7	CFB
12	Cate street capital	Berlin, New	USA	197	late 2013	6	BFB
13	EC Tychy	Tychy	Poland	184	late 2013	4.4	BFB
14	Tullis Russell	Markinch	UK	155	2013	3.7	BFB
15	Kuopion Energia	Kuopio	Finland	149	2013	3.5	BFB

6.2.4 Market view of biomass-fired power boilers

According to the IEA Task 32 database [25], in 2009, the existing co-firing potential was approximately 15 000 MW. Beurskens *et al*. [32] state that based on the EU-27 member states NREP-reports, the solid biomass electricity generation will increase from 76 800 GWh in 2010 to 154 900 GWh in 2020. They also state that the total solid biomass electric capacity will increase from 14 400 MW in 2010 to 27 700 MW. This corresponds to the yearly growth of 6.8% or roughly 13 000 MW_e per year. This would mean 0–2 large CFB boilers and 3–8 BFB boilers. There would be new co-firing in 4–8 large PF boilers. Most probably no totally new recovery boilers will be built, but replacing existing old capacity with new capacity that produces double the electricity will happen. Thus 0–2 new recovery boilers per year are predicted. The annual biomass use would increase 30 to 35 PJ. Then assuming that the large new CFB's utilize imported biomass, the biomass imports for electricity production would increase 8–15 PJ/year.

Beurskens *et al*. [32] further state that based on the EU-27 member states NREP-reports, the EU own forest biomass usage will increase by 2020 only about 33% of the 2010 usage.

The representatives of large-scale biomass boiler manufacturers Metso, Andritz [101] and Foster Wheeler [102] have been interviewed during the study in order to clarify the market view of fluidized bed boilers. According to their estimations, the potential for large biomass boilers is mainly in the US. In Europe, most interesting development will be in the UK, Benelux and Poland. In the EU area, the financial support is cut down. Both large and small biomass fired boilers will be commissioned in the future.

Realization of large biomass-fired plants in coastal areas is depending on the behaviour of the pellet market. Keen competition between the circulating fluidised bed and pulverised fuel boilers is to be expected. Very few biomass boiler projects were proceeding in early 2013, mainly due to the low coal price. The current low prices of CO_2 in the EU ETS have created a temporary setback for pellet use in co-firing.

7 DISCUSSION

This study has utilized various statistics, databases, reports and reviews relevant to the study, most of them publicly available to examine plants that either refine biomass for use in transportation and heating purposes or plants that convert biomass into heat and power. Country-level data has been compiled using both national and international statistics. Also unofficial statistics by associations have been used to determine the amounts of refined biomass. The challenges in determining accurate country-level data have been related to the variability and comparability of the figures from different sources. The only way to determine the plant-level data was to use numerous, primarily unofficial public sources including reports, reviews, plant databases and listings as well as company web pages and press releases. There is a wide variation in the accuracy of the data in these sources. Therefore, the comparability has been a major challenge. Plant level data was supplemented by non-public data and information provided by various companies, for example boiler manufacturers and electric utilities.

Despite these uncertainties, the figures do reveal interesting trends. Figure 7-1 compares the global biomass usage capacities of different categories of plants using biomass and displays the share of the TOP15-listed plants of the global capacity. Torrefaction, pyrolysis and gasification applications are not shown because of their share of the total global biomass plant capacity is very small. The capacity of biodiesel plants is 22% of the capacity of the TOP15 plants, the recovery boilers have 25%, ethanol mills have a 19% share and biodiesel 22%.

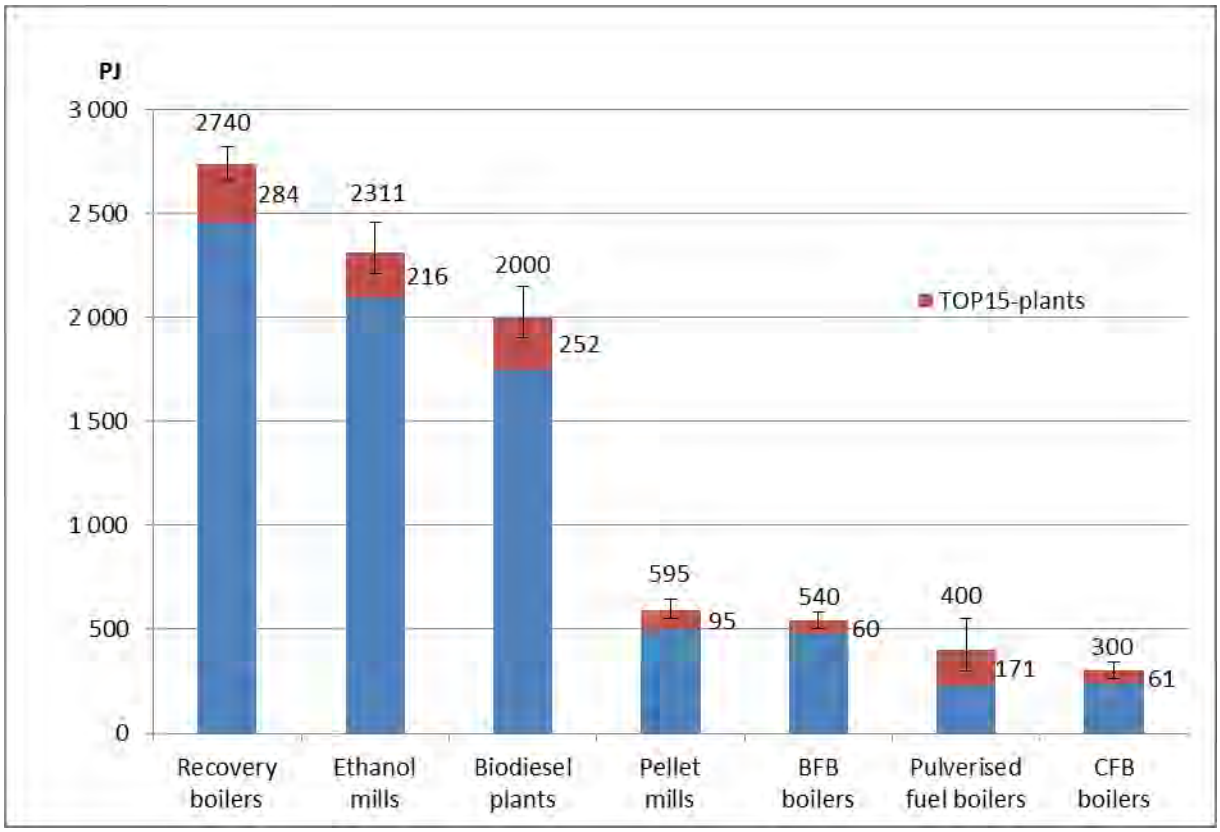

Figure 7-1 Comparison of the global capacities (PJ) of various types of biomass plants and the share of the TOP15-listed plant capacities at the end of 2012. *Ethanol, biodiesel and pellet mills capacity is measured by the energy content of the final product, and for boilers the capacity reflects the energy content of the biomass portion of the used fuels. The black lines represent the estimated margins of error for the total capacity.*

Pulp and paper industry biomass usage is still evident as the recovery boilers top the biomass utilization capacity. It can be seen that solid biomass firing in boilers is still small compared to the biomass use for liquid biofuels (ethanol and biodiesel). In all categories, the TOP15-plants represent a bit more than 10 % of the total capacity. The only exception is the pulverized fuel fired boilers.

Figure 7-2 compares the amounts of used biomass in the TOP15-plants with the global biomass use of the sector. The comparison is made according to known or estimated biomass use in the year 2012. Similarly to the plant capacities in Figure 7-1, the biomass use in Figure 7-2 reflects the energy content of input (fuel and feed) for plants that refine biomass and the share of bioenergy in the fuels for boilers. The share of biomass use in the TOP15-plants exceeds 20% of the sector's use for biodiesel plants, pulverized fuel boilers and CFB boilers, while for other categories, it is close to 10%.

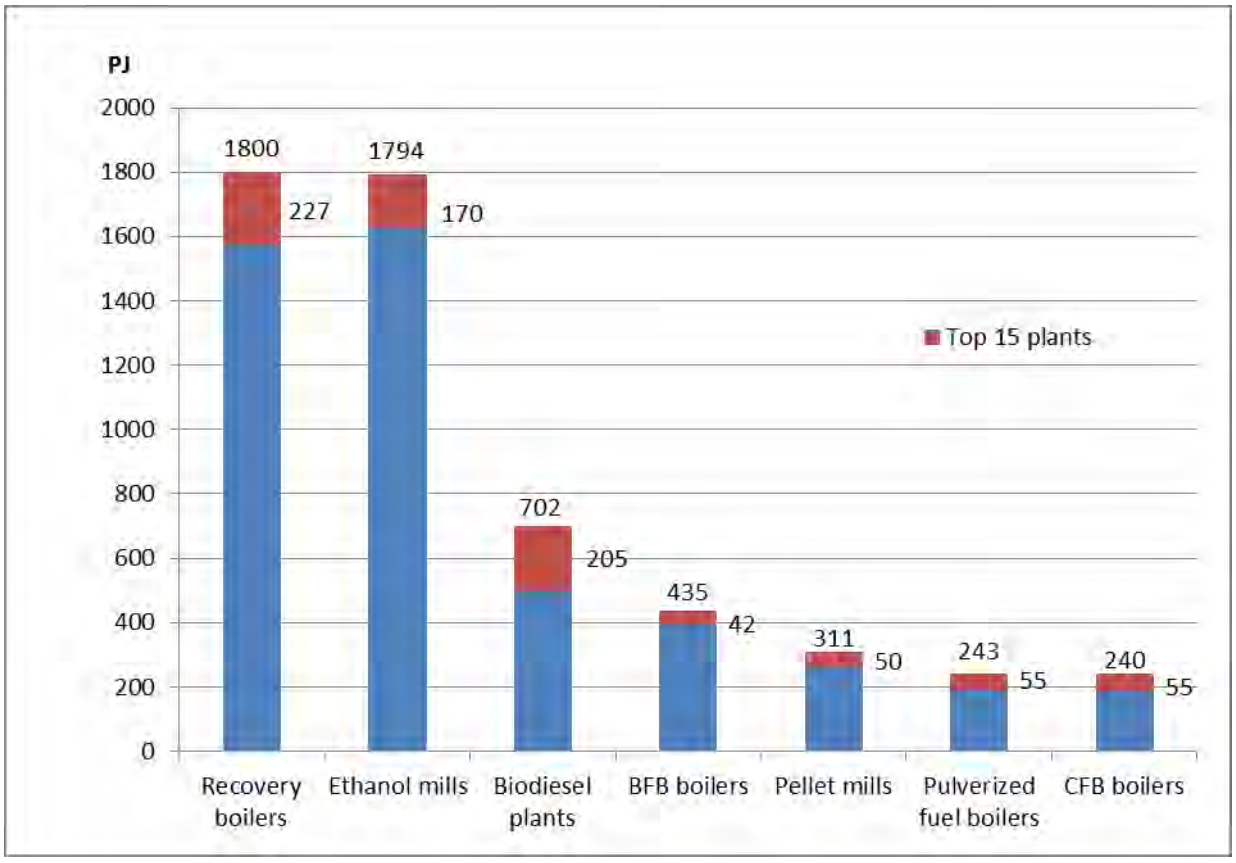

Figure 7-2 Estimated or known biomass use in TOP15-plants compared to global biomass use in various sectors in 2011. For boilers the figures are fuel consumption; for ethanol, biodiesel, and pellet mills the figures represent fuel production volumes.

Figure 7-3 shows the distribution of the capacity of the TOP15-listed plants between countries. The largest share or 25% of the large plants' capacity is located in the United States. This is because the United States is represented well in all categories. In Brazil, the share of 10% is mainly in ethanol and recovery boiler categories. These two are followed by the United Kingdom, Finland and the Netherlands. Sweden is only on place 19 because in Sweden, small- and medium scale plants are much more common.

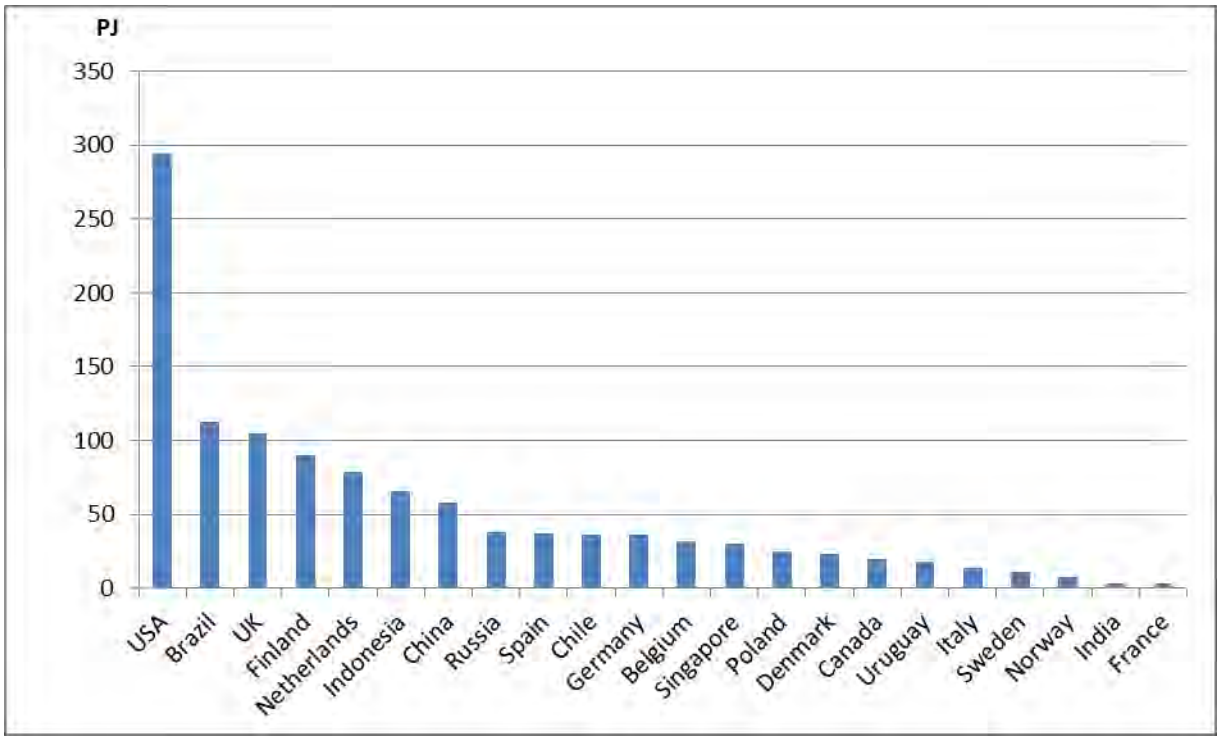

Figure 7-3 The distribution of the capacity (PJ) of the TOP15-listed plants between countries.

The distribution of imported, local and mixed feedstock in the TOP15-listed plants according to the capacities is represented in Figure 7-4. More than half (62%) of the biomass feed (counted according to the capacity of the plants) used in these plants comes from a local source. Imported biomass capacity is used mainly in pulverized firing boilers (65%) and biodiesel plants (32%). Biodiesel plants rely for 68% of their capacity on mixed biomass. Imported and mixed biomass is used mainly in Europe, whereas all non-EU countries in the top 10 of figure 7-3 (the US, Brazil, Indonesia, China, Russia and Chile) rely almost exclusively on local feedstocks. For 10% of capacity, the feedstock origin remained unknown.

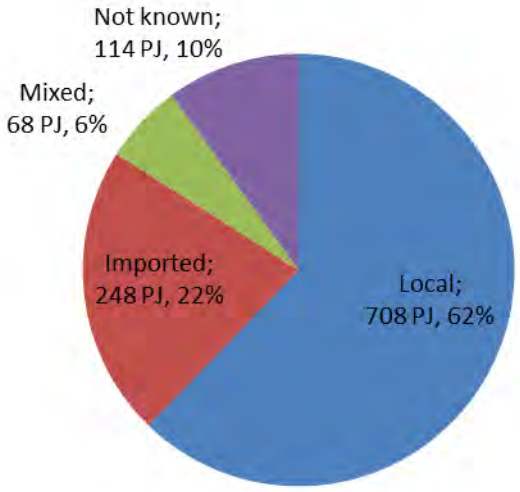

Figure 7-4 The feedstock origin in the TOP15-listed plants, the state at the end of 2012.

The study included an attempt to identify large biomass projects that are under planning or under construction. The information was gathered from public sources and via personal communication

utilising Task 40 networks. It turned out that there were hundreds of biomass projects under discussion. Some of these projects are in their initial phase, and a significant part of them will never be realised. It is also probable that a large portion of the planned projects is not identified as often the planning is not published due to commercial reasons. Within the limited resources of the study, it was not possible to investigate these projects in more detail, and therefore, the results should be considered as indicative. Figure 7-5 shows how projects currently under planning or under construction will affect the global capacity in each sector. It should be noticed that the most part of the biodiesel production capacity under planning consists of the capacities of the two plants planned in India (see Table 6-3).

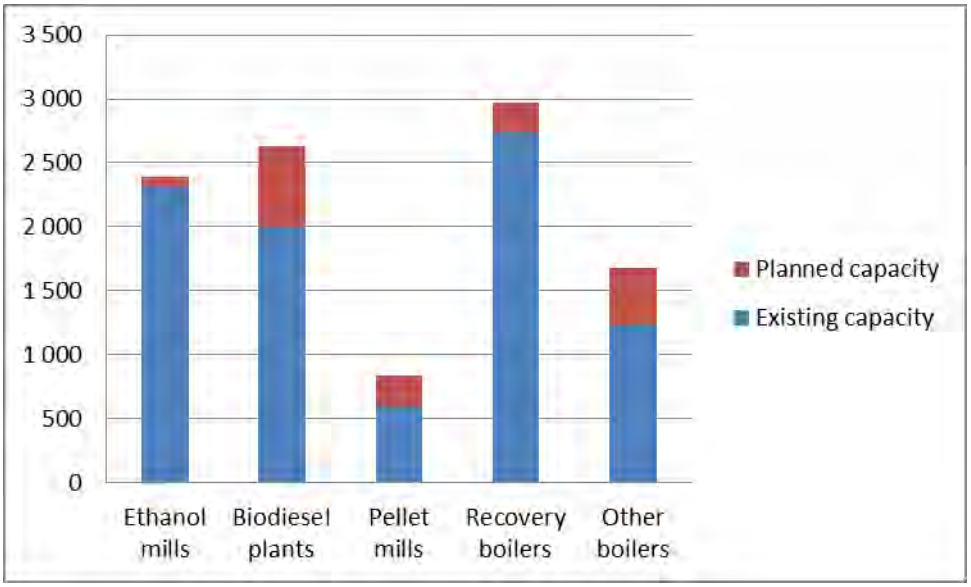

Figure 7-5 The capacity of the projects under planning or construction at the end of the year 2012 compared with the global existing capacity.

Beurskens *et al*. [32] sum up that based on the EU-27 member states NREAP-reports, the EU biomass electricity generation would more than double from 2010 to 2020. As most of this capacity increase would happen in category 'Other boilers', the red portion of that bar should approach the size of the blue portion. As mentioned earlier, the summary is based on predictions around 2010. We can conclude that they have not yet fully materialized. We can see that there is higher growth in biodiesel than in ethanol.

8 CONCLUSIONS

The use of biomass for energy purposes is growing in the world. According to the results of this study, a significant number of new large plants both to refine and process biomass for energy carrier purposes (biofuels) as well as convert biomass into heat and power are being built around the world.

Most part of energy biomass is used in the residential sector in developing countries. Industrial and transportation use is however concentrated into quite a small part of the world. Industrial use of biomass forms 15% of the global biomass use, and nearly half of it takes place in India, Brazil and the US. Industrial sector uses primarily solid biomass for energy purposes, especially industrial and agricultural residues. Biomass consumption in transportation sector is also concentrated into only a few countries. Brazil and the US use the most part of fuel ethanol, and biodiesel is consumed mainly in the EU area.

Large plants that process or refine biomass are located primarily in the industrialised countries. The largest plants are producing ethanol and biodiesel; pellet plants are slightly smaller and gasification, torrefaction and pyrolysis facilities are rare and significantly smaller. Biomass is processed mainly near the biomass source using local feedstock; an exception of this is the biodiesel production. It seems that the situation will remain similar in the future.

Pellets are produced mainly in areas where woody biomass is easily available, most of them in North America and Europe. Traditionally, pellet mills have been located near sawmills, in which case the feedstock, typically saw dust, has been acquired directly. Currently, large pellet mills use also wood residues and in some cases wood logs as raw material, but the feedstock is mainly local. Pellets are used mostly in the EU area, and therefore the major pellet trade streams are from North America to Europe. Most large pellet mill projects under planning are located in North America, and the production of them is aimed almost entirely for the export to Europe. These plans, if realised, will increase further the pellet trade streams from within next few years.

Ethanol is produced and used mainly in the US and Brazil. The majority of the largest ethanol plants are located in the US, where ethanol is made using corn as raw material. Brazilian ethanol is sugarcane-based, and there are more ethanol mills, but they are significantly smaller than in the US. Large ethanol producers use local feedstock. Planned ethanol mills found for this study are smaller than the largest existing ones; the capacity of the largest one is 10 PJ/a while the largest existing mills is able to produce 24 PJ/a. Planned mills will be located mainly in the US.

Biodiesel is produced mostly in the EU area, United States, Brazil and Argentina, and the largest plants are located in the EU area and Singapore. Vegetable oils such as palm oil and rapeseed oil are the main feedstocks, and in the largest plants, the feedstock is typically imported or a mixture of imported and local material. Vegetable oils are widely traded and have a high energy density, which enables efficient transportation. Biodiesel plants are under planning in many industrialised countries, but the largest ones in India and Brazil. Despite these, the planned plants are substantially smaller than the existing ones. In the US, Finland and France there are plans for facilities producing renewable diesel from lignocellulosic feedstock.

Comparison of the global capacities (PJ/a) of biomass user plants and the share of the TOP15-listed plants at the end of 2012 showed that they are using large amounts of biomass but in no category (with perhaps an exception in the co-firing category) do they dominate the biomass usage. Large new plants can however greatly affect the biomass markets at country level. And while the use of raw biomass will likely remain local, the trade of refined biofuels such as bioethanol, biodiesel and wood pellets will likely continue to increase in the near future.

The aim of this study was to identify the largest biomass plants and their biomass use. As biomass energy use is increasing relatively rapidly, new projects are introduced continuously and new plants are taken into operation continuously. Thus the data in this report will become outdated soon. Therefore, there is a clear need to update the plant lists. The authors hope that this work can provide a starting point for further studies to increase information availability on how energy biomass markets will develop in coming years.

REFERENCES

1. IEA. *Energy statistics*. 2012 22 May]; Available from: http://www.iea.org/stats/index.asp.
2. Heinimö, J. and M. Junginger, *Production and trading of biomass for energy—an overview of the global status.* Biomass and Bioenergy, 2009. **33**(9): p. 1310–1320.
3. Statistic Finland. 2012 [cited 2012 July 31]; Available from: http://www.stat.fi/index_en.html.
4. Statistics Sweden. 2012 [cited 2012 July 31]; Available from: http://www.scb.se/default____2154.aspx.
5. Destatis - Federal Statistical Office in Germany. 2012 [cited 2012 June 31]; Available from: https://www.destatis.de/EN/Homepage.html.
6. Ministry of Energy and Mines, *Brazilian Energy Balance*, 2011, Brazilian Federal Government.
7. European Union Statistical Office. *Statistics*. 2012 [cited 2012 August 20]; Available from: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.
8. FAOSTAT data. 2012 3 May]; Available from: http://faostat.fao.org/.
9. Brazilian Sugarcane Industry Association (União da Indústria de Cana-de-açúcar - UNICA). 2012 [cited 2012 May 23]; Available from: http://english.unica.com.br/.
10. Brazilian Sugarcane Industry Association (União da Indústria de Cana-de-açúcar - UNICA). *Statistics*. 2012 [cited 2012 May 21]; Available from: http://english.unica.com.br/dadosCotacao/estatistica/.
11. Union of Bioenergy Producers (UDOP). 2012 [cited 2012 August 13]; Available from: http://www.udop.com.br/index.php.
12. Renewable Fuels Association (RFA). 2012 [cited 2012 July 2]; Available from: http://www.ethanolrfa.org/.
13. National Biodiesel Board (NBB). 2012 [cited 2012 September 5]; Available from: http://www.nbb.org/home.
14. Canadian Renewable Fuels Association (CRFA). *Plant locations*. 2010 [cited 2012 June 19]; Available from: http://www.greenfuels.org/en/industry-information/plants.aspx.
15. European Biodiesel Board (EBB). *Statistics*. 2012 [cited 2012 May 15]; Available from: http://www.ebb-eu.org/stats.php.
16. Reuters. *Factbox: Bioethanol plants across Europe*. 2010 [cited 2012 May 30]; Available from: http://www.reuters.com/article/2010/02/08/us-biofuels-europe-bioethanol-idUSTRE6172JX20100208.
17. Reuters. *Factbox: Biodiesel plants in the EU*. 2010 [cited 2012 May 30]; Available from: http://www.reuters.com/article/2010/02/08/us-biofuels-europe-biodiesel-idUSTRE6172JY20100208.
18. Bioenergy International Magazine, *World of Pellets map*, 2013.
19. Ethanol Producer Magazine (EPM). *Ethanol plants listing, USA*. 2012 [cited 2012 August 20]; Available from: http://www.ethanolproducer.com/plants/listplants/USA/.
20. German Biofuels Industry Association (VBD). *Informationen: Biokraftsoffe in Deutschland*. 2012 [cited 2012 May 28]; Available from: http://www.biokraftstoffverband.de/downloads/2122/factsheet_biodiesel.
21. National Renewable Energy Laboratory (NREL). *BioEnergy Atlas*. 2012 [cited 2012 August 14]; Available from: http://www.nrel.gov/biomass/data_resources.html.
22. National Energy Technology Laboratory (NETL). *Worldwide Gasification Database*. 2010 [cited 2012 September 3]; Available from: http://www.netl.doe.gov/technologies/coalpower/gasification/worlddatabase/index.html.
23. Agência Nacional do Petróleo Gás Natural e Biocombustíveis (ANP). *Anuário Estatístico*. 2011; Available from: http://www.anp.gov.br/?id=661.

24. Agência Nacional do Petróleo Gás Natural e Biocombustíveis (ANP), *Biocombustíveis—Etanol*, 2012.
25. IEA Bioenergy Task 32. *Database of Biomass Cofiring initiatives*. 2009 [cited 2013 3 March]; Available from: http://www.ieabcc.nl/.
26. Lappeenranta University of Technology (LUT), *Internal database*, 2013.
27. Koornneef, J., M. Junginger, and A. Faaij, *Development of fluidized bed combustion—An overview of trends, performance and cost.* Progress in Energy and Combustion Science, 2007. **33**(1): p. 19–55.
28. Cocchi, M., et al., *Global Wood Pellet Industry—Market and Trade Study*, 2011, IEA Bioenergy Task 40.
29. Global Agricultural Information Network (GAIN). 2012 [cited 2012 15 October]; Available from: http://gain.fas.usda.gov/Pages/Default.aspx.
30. Bridgwater, A., *Review of fast pyrolysis of biomass and product upgrading.* Biomass and Bioenergy, 2012. **4**(1): p. 68–94.
31. Deutmeyer, M., et al., *Possible effect of torrefaction on biomass trade*, 2012, IEA Bioenergy Task 40. p. 48.
32. Beurskens, L., M. Hekkenberg, and P. Vethman, *Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States*, 2011, Energy Research Center of the Netherlands, European Environment Agency. p. 234.
33. European Commission (EC). *Climate Action - NER 300*. 2012 [cited 2012 September 6]; Available from: http://ec.europa.eu/clima/funding/ner300/index_en.htm.
34. Lamers, P., et al., *International bioenergy trade-A review of past developments in the liquid biofuel market.* Renewable & Sustainable Energy Reviews, 2011. **15**(6): p. 2655–2676.
35. Lamers, P., et al., *Developments in international solid biofuel trade—An analysis of volumes, policies, and market factors.* Renewable and Sustainable Energy Reviews, 2012. **16**(5): p. 3176–3199.
36. Heinimö, J., P. Lamers, and T. Ranta. *International trade of energy biomass—an overview of the past development*. In *21st European Biomass Conference. 3–7 June*. 2013. Copenhagen, Denmark.
37. Aradhey, A., *India—Biofuels Annual*, 2012, USDA Foreign Agricultural Service, Global Agricultural Information Network.
38. Walter, A. and P. Dolzan, *Country Report—Brazil*, 2012, IEA Bioenergy Task 40.
39. Hess, R., et al., *Country Report—United States*, 2010, IEA Bioenergy Task 40.
40. U.S. Energy Information Administration (EIA). *Monthly Energy Review*. 2012 [cited 2012 May 24]; Available from: http://www.eia.gov/totalenergy/data/monthly/#renewable.
41. Barros, S., *Brazil—Biofuels Annual*, 2011, USDA Foreign Agricultural Service, Global Agricultural Information Network.
42. Thrän, D., et al., *Country Report—Germany*, 2012, IEA Bioenergy Task 40.
43. REN21, *Renewables 2012 Global Status Report*, 2012: Paris. p. 176.
44. AEBIOM, *European Bioenergy Outlook 2012*, 2012: Brussels. p. 124.
45. Bradley, D. and K. Bradburn, *Economic Impact of Bioenergy in Canada 2011*, 2012. p. 26.
46. Global Agricultural Information Network (GAIN). 2013 [cited 2013 June 24]; Available from: http://gain.fas.usda.gov/.
47. Walker, S., *Wood-Based Bioenergy in North America*, 2013, RISI.
48. *Individual company websites and press releases*, 2012.
49. Biomass Magazine. *Pellet producers list*. 2013 [cited 2013 April 20]; Available from: http://biomassmagazine.com/plants/listplants/pellet/US/.
50. Canadian Biomass. *Pellet map*. 2013 [cited 2013 April 24]; Available from: http://www.canadianbiomassmagazine.ca/images/stories/cbm_pelletmap2013_lr.pdf.
51. Bradley, D. and E. Thiffault, *Country Report - Canada*, 2012, IEA Bioenergy Task 40.
52. RWE Innogy. 2012 [cited 2012 October 10]; Available from: http://www.rwe.com/web/cms/en/86134/rwe-innogy/.

53. Chum, H., et al., *Bioenergy*, in *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, O. Edenhofer, et al., Editors. 2011, Cambridge University Press: Cambridge, UK and New York, NY, USA.
54. ePURE. *Statistics—Production capacity installed*. 2012 5 December 2012 [cited 2013 12 March]; Available from: http://www.epure.org/statistics/production-capacity-installed.
55. Goh, C.S., et al., *Impacts of sustainability certification on bioenergy markets and trade*, in *Strategic Inter-Task Study: Monitoring Sustainability Certification of Bioenergy*2013, IEA Bioenergy task 40, Task 43 and Task 38. p. 61.
56. U.S. Census Bureau. *International Statistics*. 2012 [cited 2012 October 10]; Available from: http://www.census.gov/compendia/statab/cats/international_statistics.html.
57. Global Biofuels Center. *Global ethanol and biodiesel production capacity*. 2012 [cited 2012 October 15]; Available from: http://www.globalbiofuelscenter.com/nm_top5.aspx.
58. U.S. Energy Information Administration (EIA). *Monthly Biodiesel Production Report*. 2013 [cited 2013 June 24]; Available from: http://www.eia.gov/biofuels/biodiesel/production/.
59. Neste Oil. 2012 [cited 2012 August 14]; Available from: http://www.nrel.gov/biomass/data_resources.html.
60. Jones, J. *Torrefaction process, overview*. 2012 March/28/2012 [cited 2012 July 11]; Available from: http://www.engineering.leeds.ac.uk/short-courses/documents/JJWelcome.pdf.
61. NORAM Engineering and Constructors Ltd, *Torrefaction Technology Evaluation*, in *BC Bioenergy Network Conference* 2011.
62. Kleinschmidt, C., *Overview of international developments in torrefaction*, in *Torrefaction Workshop*2011, IEA Bioenergy Task 40 and Task 32: Graz, Austria.
63. Koppejan, J., et al., *Status overview of torrefaction technologies*, 2012: Enschede, Netherlands.
64. Brown, T.R. and R.C. Brown, *Commercial-scale cellulosic biofuels projects in the United States. Summary report*, 2013. p. 5.
65. Vakkilainen, E., *New innovative technologies to convert wood to energy*, in *NOBRE Workshop*2012: Turku, Finland.
66. European Climate Foundation, et al., *Biomass for heat and power—Opportunity and economics*, 2010, European Climate Foundation: The Hague, Netherlands.
67. European Technology Platform for Zero Emission Fossil Fuel Power Plants, *Biomass with CO2 Capture and Storage (Bio-CCS); The way forward for Europe*, 2012. p. 32.
68. FAO forest data. 2012 18 December 2012; Available from: http://faostat.fao.org/DesktopDefault.aspx?PageID=626&lang=en#ancor.
69. Spielthoff, H., *Status of biomass gasification for power production.* IFRF Combustion Journal, 2001.
70. Drfit, B.v.d., *IEA Task 33—Biomass Gasification*, 2011, IEA Task 33: IEA Meeting, Delft, Netherlands.
71. IEA Bioenergy Task 33. *Thermal Gasification Facilities—Database*. 2012 [cited 2012 July 21]; Available from: http://www.ieatask33.org/content/thermal_gasification_facilities.
72. Vaskiluodon Voima Oy. *Kaasutuslaitoprojekti*. 2012 [cited 2012 October 3]; Available from: http://www.vv.fi/vaasan_voimalaitos/kaasutuslaitosprojekti.
73. Lahti Energia Oy. 2012 [cited 2012 September 4]; Available from: http://www.lahtienergia.fi/lahti-energia.
74. Andritz AG, *Biomass drying before gasification*, in *World of Separation*2012.
75. Kurkela, E. *Biomass gasification technologies for advanced power systems and synfuels—Status and present R&D activities in Finland*. 2009 January/29/2009 [cited 2012 October 16]; Available from: http://www.vtt.fi/files/projects/gasification/gasification_activities_in_finland_2009.pdf.
76. European Biofuels Technology Platform (EBTP). *Biomass to Liquids*. 2012 [cited 2012 October 9]; Available from: http://www.biofuelstp.eu/btl.html.

77. Bengtsson, S., *VVBGC demonstration plant activities at Värnamo.* Biomass and Bioenergy, 2011. **35,** Supplement 1(0): p. S16–S20.
78. Middelkamp, J., *Biomass co-firing and full repowering—Recent developments and KEMA's expectations*, in *IEA workshop on Cofiring Biomass with coal* 2012: Copenhagen.
79. European Renewable Energy Council EREC, *RE-Thinking 2050—A 100% Renewable Energy Vision for the European Union*, 2010.
80. Khan, A.A., et al., *Biomass combustion in fluidized bed boilers: Potential problems and remedies.* Fuel Processing Technology, 2009. **90**(1): p. 21–50.
81. Coda Zabetta, E., et al., *Foster Wheeler Experience with Biomass and Waste in CFBs*, in *33rd Clearwater Conference*2008: Clearwater, Florida, U.S.A. p. 15.
82. Hupa, M., *Recent Progress in Large Scale Energy Use of Biomass and Waste-Role of Fluidized Bed Technology*, in *Combustion, Carbon Capture and Storage—CCCS*2009, DTU Chemical Engineering: Lyngby, Denmark. p. 23.
83. Koza, D. and M. Shuang, *Options for biomass fuels utilization in power plants.* Power Engineering, 2011: p. 60–68.
84. Rautanen, M., *Bioenergy—Closing the CO2 loop*, in *Renewable Energy for Europe—Research in Action*2006, European Commission: Charlemagne Building, Brussels, Belgium.
85. Nielsen, S., *Suzano to Invest $534 Million in Brazil Wood Pellet Production*, in *Bloomberg News*2011, Bloomberg.
86. Zilkha Biomass Energy. *The Zilkha Black Pellet*. 2013 14 March 2013]; Available from: http://www.zilkha.com/our-waterproof-pellet/.
87. Miktech Oy. 2012 11 September 2012]; Available from: http://www.miktech.fi/.
88. Soybean and Corn Advisor. *Brazil Government promotes small start-up ethanol producers*. 2012 [cited 2012 October 15]; Available from: http://www.soybeansandcorn.com/news/Apr5_12-Brazil-Governement-Promotes-Small-Start-up-Ethanol-Producers.
89. Drax Group. *Our History*. Available from: http://www.draxgroup.plc.uk/aboutus/history/.
90. IHB (Fordaq S.A.), *Drax plans to create the biggest pellet fired power station*, 2012.
91. Lundgren, K. and A. Morales, *Biggest English polluter spends $1 billion to burn wood*, in *Bloomberg Businessweek*2012.
92. Foster Wheeler, *Samcheok Factsheet. Samcheok Green Power Project. A New Era in Clean Coal Technology*, 2011.
93. Jäntti, T., et al., *Samcheok Green Power 4 x 550 MWe Supercritical Circulating Fluidized-Bed Steam Generators in South Korea*, in *PowerGen Europe*2012, Foster Wheeler Energia Oy: Colon, Germany.
94. Andritz Pulp&Paper and Recovery and power division, *Growing reference base for green energy production: Latest deliveries in operation or under construction*, 2012.
95. Forestry Commission and Biomass Energy Center, *UK Biomass power stations current and planned*, 2011.
96. MGT Power. *Tees Renewable Energy plant*. Available from: http://www.mgtpower.com/projects/tees-renewable-energy-plant/.
97. Ollila, J., *Metso to deliver power plant to Bomhus Energi, Sweden*, 2010, Metso Corporation.
98. Ollila, J., *Metso to convert coal fired boiler to biomass fired boiler for EC Tychy in Poland*, 2011, Metso Corporation.
99. Ollila, J., *Metso to rebuild combustion technology at Kuopion Energia power plant in Finland*, 2012, Metso Corporation.
100. Foster Wheeler, *Contract Announcements: February 28, 2013 through January 10, 2008*, 2013.
101. Kauranen, T., E. Vakkilainen and J. Heinimö, Editors. 2012, Andritz: Varkaus, Finland.
102. Hotta, A. and K. Nuortimo, J. Heinimö, Editor 2012, Foster Wheeler Energia Oy.

List of largest pellet mills

No.	Company	Location	Country	Capacity 1000 t/a	Capacity PJ/a
1	Vyborgskay Cellose	Leningrad Region	Russia	900	15
2	Georgia Biomass (RWE)	Waycross GA	USA	800	14
3	Green Circle (JCE Group)	Cottondale FL	USA	550	9
4	Biowood	Averøy	Norway	450	8
5	Pinnacle Pellet	Burns Lake BC	Canada	400	7
6	Enviva	Hertford, Ahoskie, NC	USA	380	6
7	Pacific BioEnergy	Prince George BC	Canada	360	6
8	German Pellets	Wismar	Germany	256	4
9	German Pellets	Herbrechtingen	Germany	256	4
10	Arkaim	Khabarovsk	Russia	250	4
11	Fram Renewable Fuels, Appling Country Pellets	Baxley, GA	USA	220	4
12	Pinnacle Pellet Meadowbank	Strathnaver BC	Canada	200	3
13	Ankit	Bengalooru	India	200	3
14	Hongyi Biofuels	Linyl, Shandong	China	200	3
15	Premium Pellet	Vanderhoof BC	Canada	190	3
16	Graanul Invest	Incukalns	Latvia	180	3
17	Southern Resources	Ho Chi Minh	Vietnam	180	3
18	SIA Graanul Invest	Launkalne	Latvia	180	3
19	Graanul Invest, Helme Graanul	Patkula	Estonia	180	3
20	SCA BioNorr	Härnösand	Sweden	160	3
21	Latgran	Jekabpils	Latvia	155	3
22	Latgran	Kraslava	Latvia	155	3
23	Houston Pellet (Pinnacle-Canfor)	Houston BC	Canada	150	3
24	Pfeifer	Kundl	Austria	150	3
25	IBV	Burtonville	Belgium	150	3
26	Pinnacle Pellet WL	Williams Lake BC	Canada	150	3
27	Vattenfall Biopillefabrik	Köge	Denmark	150	3
28	German Pellets Sachsen	Torgau	Germany	150	3
29	Biogy	Chiriqui	Panama	150	3
30	Pfeifer (Anton Heggenstaller)	Unterbernbach	Germany	150	3
31	Bo'en Bioenergy	Guangzhou, Guangdong	China	150	3
32	Stelmet	Zielona Gora	Poland	144	2
33	Vinafood	Dong Thap	Vietnam	140	2
34	Vapo	Vildbjerg	Denmark	140	2
35	Binderholz Deutschland	Kösching	Germany	140	2
36	Lignetics of West Virginia	Glenville WV	USA	140	2
37	Enviva Pellets Wiggins	Perkinston MS	USA	136	2
38	Barlinek	Barlinek	Poland	135	2
39	Trebio, GF Energy	Portage-du-Fort, QC	Canada	130	2

40	Ug Rusi	Rostov-on-Done	Russia	130	2
41	Skellefteå Kraft	Hedensbyn, Skellefteå	Sweden	130	2
42	German Pellets	Ettenheim	Germany	128	2
43	Plospan Bio-Energy	Waardenburg	The Netherlands	125	2
44	Piveteau	Sainte Florence	France	120	2
45	Enerpellets	Pedrograo Grande	Portugal	120	2
46	Atikokan Renewable Fuels	Atikokan ON	Canada	120	2
47	Energex Pellet Fuel	Lac-Mégantic, QC	Canada	120	2
48	Granules LG	St-Félicien, QC	Canada	120	2
49	NRW Pellets (German Pellets/RWE)	Erndtebrück	Germany	120	2
50	EKO Energy		Germany	120	2
51	Italiana Pellets	Pavia, Lombardia	Italy	120	2
52	Pinewells (Visabeira)	Arganil	Portugal	120	2
53	Enisey	Krasnoyarsky Region	Russia	120	2
54	Lesozavod 25	Arkhangelsk	Russia	120	2
55	Neova	Vaggeryd	Sweden	120	2
56	Huafeng agr. Biotechn.	Yangzhong, Jiangsu	China	120	2
57	Hengsen Bioenergy	Taicang, Jiangsu	China	120	2
58	Gregor Ziegler Thermospan	Plössberg	Germany	120	2
59	EC Bioenergie	Mittenaar	Germany	115	2
60	Lee Energy	Crossville AL	USA	115	2
61	Viridis (former Enligna)	Upper Muquodoboit NS	Canada	110	2
62	Laxå Pellets, (OK Eco. För.)	Laxå	Sweden	110	2
63	Graanul Invest	Ebavere Graanul	Estonia	110	2
64	Holzindustrie Schweighofer	Sebes	Romania	110	2
65	Maine Wood Pellets	Athens ME	USA	110	2
66	Techpellet	Famalicao	Portugal	110	2
67	Pellets Power 2, Gesfinu Group	Setubal	Portugal	105	2
68	Graanul Invest	Imavere, Paide	Estonia	105	2
69	BioEnergi i Luleå	Luleå	Sweden	105	2
70	Holzindustrie Schweighofer	Radauti	Romania	105	2
71	Energy Pellets Moerdijk	Moerdijk	The Netherlands	104	2
72	Erda	Bertrix	Belgium	100	2
73	Pellets Power, Gesfino Group	Viseu	Portugal	100	2
74	2F Investissement	Aire-sur-l´Adour	France	100	2
75	Baltic Wood	Mazeikiai	Lithuania	100	2
76	Canadian Biofuel	Springford, ON	Canada	100	2
77	Shaw Resources	Belledune NB	Canada	100	2
78	Vapo	Vilppula	Finland	100	2
79	EDF Trading (earlier VisNova)	Schwedt	Germany	100	2
80	Hungaropellet, Raklap es Tüzep	Lajosmizse	Hungary	100	2
81	Stora Enso	Grums	Sweden	100	2

82	Balcas Brites	Invergordon, Scotland	United Kingdom	100	2
83	Drax	Yorkshire	United Kingdom	100	2
84	Low Country Biomass	Ridgeland, SC	USA	100	2
85	Biomass Energy, EBRE	Burnpass VA	USA	100	2
86	Curran	Massena NY	USA	100	2
87	Nature's Earth Pellet Energy	Reform, AL	USA	100	2
88	MDL Metra Duta Lestari	Merauke	Indonesia	100	2
89	Xianhu	Shenyang, Liaoning	China	100	2
90	Xintiandi Bioenergy	Feicheng, Shandong	China	100	2
91	Sanli New Energy	Nanyang, Henan	China	100	2
92	Xuzhou Wanguo Bioenergy Tech	Xuzhou, Jiangsu	China	100	2
93	Dingliang Bioenergy, Guangde, Anhui		China	100	2
94	Foshan Woodsun Wood Industry	Foshan, Guangdong	China	100	2
95	Lantmännen Agroenergi	Norberg	Sweden	96	2
96	B&B Bioenergie	Betriebstätte, Calau	Germany	90	2
97	Bear Mountain Forest Products	Brownsville OR	USA	90	2
98	Binderholz	Fügen	Austria	90	2
99	BioPell GmbH		Germany	90	2
100	Enviva	Amory	USA	90	2

List of largest ethanol mills

No.	Mill	Location	Country	Capacity Ml/a	Capacity PJ
1	Archer Daniels Midland	Columbus, NE	USA	1 136	24.1
2	Archer Daniels Midland	Decatur, IL	USA	1 098	23.3
3	Archer Daniels Midland	Cedar Rapids, IA	USA	1 041	22.1
4	Archer Daniels Midland	Cedar Rapids, IA	USA	908	19.3
5	Archer Daniels Midland	Clinton, IA	USA	897	19.0
6	Cargill, Inc.	Blair, NE	USA	738	15.6
7	Aventine Renewable Energy, LLC	Pekin, IL	USA	606	12.8
8	Tharaldson Ethanol	Casselton, ND	USA	568	12.0
9	Valero Renewable Fuels	Jefferson Junction, WI	USA	492	10.4
10	Abengoa Bioenergy Netherlands	Rotterdam	Netherlands	480	9.6
11	Green Plains Renewable Energy	Bluffton, IN	USA	454	9.6
12	Green Plains Renewable Energy	Obion, TN	USA	454	9.6
13	Valero Renewable Fuels	Aurora, SD	USA	454	9.2
14	Absolute Energy, LLC	St. Ansgar, IA	USA	435	9.2
15	BioFuel Energy - Buffalo Lake Energy, LLC	Fairmont, MN	USA	435	9.2
16	BioFuel Energy - Pioneer Trail Energy, LLC	Wood River, NE	USA	435	9.2
17	Flint Hills Resources LP	Fairbank, IA	USA	435	9.2
18	Golden Grain Energy, LLC	Mason City, IA	USA	435	9.1
19	Sunoco	Volney, NY	USA	431	8.8
20	Vivergo Fuels	Hessle	UK	420	8.8
21	ABE Fairmont	Fairmont, NE	USA	416	8.8
22	Aventine Renewable Energy, LLC	Mount Vernon, IN	USA	416	8.8
23	Arkalon Energy, LLC	Liberal, KS	USA	416	8.8
24	Big River United Energy	Dyersville, IA	USA	416	8.8
25	Flint Hills Resources LP	Menlo, IA	USA	416	8.8
26	Flint Hills Resources LP	Shell Rock, IA	USA	416	8.8
27	Guardian Energy	Janesville, MN	USA	416	8.8
28	Hankinson Renewable Energy, LLC	Hankinson, ND	USA	416	8.8
29	NuGen Energy	Marion, SD	USA	416	8.8
30	Pennsylvania Grain Processing LLC	Clearfield, PA	USA	416	8.8
31	Platinum Ethanol, LLC	Arthur, IA	USA	416	8.8
32	POET Biorefining - Chancellor	Chancellor, SD	USA	416	8.8
33	Southwest Iowa Renewable Energy, LLC	Council Bluffs, IA	USA	416	8.8
34	The Andersons Clymers Ethanol LLC	Clymers, IN	USA	416	8.8
35	The Andersons Marathon Ethanol LLC	Greenville, OH	USA	416	8.8
36	Valero Renewable Fuels	Albert City, IA	USA	416	8.8
37	Valero Renewable Fuels	Charles City, IA	USA	416	8.8
38	Valero Renewable Fuels	Ft. Dodge, IA	USA	416	8.8
39	Valero Renewable Fuels	Hartley, IA	USA	416	8.8
40	Valero Renewable Fuels	Welcome, MN	USA	416	8.8

41	Valero Renewable Fuels	Albion, NE	USA	416	8.8
42	Valero Renewable Fuels	North Linden, IN	USA	416	8.8
43	Valero Renewable Fuels	Bloomingburg, OH	USA	416	8.7
44	White Energy	Plainview, TX	USA	416	8.7
45	São Martinho	Pradópolis, SP	Brazil	412	8.6
46	Columbia Pacific Biorefinery	Clatskanie, OR	USA	409	8.4
47	Glacial Lakes Energy, LLC - Mina	Mina, SD	USA	405	8.4
48	Ensus	Wilton	UK	400	8.4
49	Suncor St. Clair Ethanol Plant	Ontario	Canada	400	8.2
50	Flint Hills Resources LP	Iowa Falls, IA	USA	397	8.0
51	Murphy Oil	Hereford, TX	USA	397	8.0
52	Tate & Lyle	Loudon, TN	USA	397	8.0
53	New Energy Corp.	South Bend, IN	USA	386	8.0
54	Archer Daniels Midland	Peoria, IL	USA	379	8.0
55	Archer Daniels Midland	Columbus, NE	USA	379	8.0
56	Big River Resources Galva, LLC	Galva, IL	USA	379	8.0
57	Big River Resources, LLC	West Burlington, IA	USA	379	8.0
58	Cardinal Ethanol	Union City, IN	USA	379	8.0
59	Glacial Lakes Energy, LLC	Watertown, SD	USA	379	8.0
60	Green Plains Renewable Energy	Lakota, IA	USA	379	8.0
61	Green Plains Renewable Energy	Central City, NE	USA	379	8.0
62	Heartland Corn Products	Winthrop, MN	USA	379	8.0
63	Homeland Energy	New Hampton, IA	USA	379	8.0
64	Illinois River Energy, LLC	Rochelle, IL	USA	379	8.0
65	Louis Dreyfus Commodities	Grand Junction, IA	USA	379	8.0
66	Marquis Energy, LLC	Hennepin, IL	USA	379	8.0
67	One Earth Energy	Gibson City, IL	USA	379	7.4
68	Patriot Renewable Fuels, LLC	Annawan, IL	USA	379	7.4
69	Southwest Georgia Ethanol, LLC	Camilla, GA	USA	379	7.4
70	White Energy	Hereford, TX	USA	379	7.2
71	CropEnergies AG	Zeitz	Germany	360	7.1
72	Little Sioux Corn Processors, LP	Marcus, IA	USA	348	7.1
73	POET Biorefining - Cloverdale	Cloverdale, IN	USA	348	7.1
74	Equipav	Sao Paulo state	Brazil	347	6.7
75	Illinois Corn Processing	Pekin, IL	USA	341	6.3
76	Abengoa Bioenergy Corp.	Madison, IL	USA	333	6.0
77	Abengoa Bioenergy Corp.	Mt. Vernon, IN	USA	333	5.9
78	Abengoa Bioenergy Corp.	Ravenna, NE	USA	333	5.5
79	Da Barra		Brazil	316	5.5
80	BioWanze	Wanze	Belgium	300	5.5
81	Tereos	Origny	France	300	5.5
82	POET Biorefining - Big Stone	Big Stone City, SD	USA	299	5.5
83	Husker Ag, LLC	Plainview, NE	USA	284	5.5
84	Colorado	Guaíra, SP	Brazil	277	5.5

85	POET Biorefining - Gowrie	Gowrie, IA	USA	261	5.5
86	POET Biorefining - Jewell	Jewell, IA	USA	261	5.5
87	POET Biorefining - Alexandria	Alexandria, IN	USA	257	5.3
88	POET Biorefining - Fostoria	Fostoria, OH	USA	257	5.2
89	POET Biorefining - Leipsic	Leipsic, OH	USA	257	5.2
90	POET Biorefining - Marion	Marion, OH	USA	257	5.2
91	POET Biorefining - Mitchell	Mitchell, SD	USA	257	5.2
92	POET Biorefining - North Manchester	North Manchester, IN	USA	257	5.0
93	POET Biorefining - Portland	Portland, IN	USA	257	4.9
94	Tereos	Lillebonne	France	250	4.8
95	AB Bioenergy France	Lacq	France	250	4.8
96	São José - Macatuba	Macatuba, SP	Brazil	248	4.8
97	Santa Elisa	Sertãozinho, SP	Brazil	247	4.8
98	Osage Bio-Energy	Hopewell, VA	USA	246	4.8
99	POET Biorefining - Corning	Corning, IA	USA	246	4.8
100	Vale do Rosario	Sao Paulo state	Brazil	245	4.8

List of largest biodiesel plants

No.	Company	Location	Country	Capacity 1000 t/a	Capacity PJ/a
1	Neste Oil	Rotterdam	Netherlands	800	29,8
2	Neste Oil	Singapore	Singapore	800	29,8
3	Biopetrol	Rotterdam	Netherlands	650	24,2
4	Infinita Renovables	Castellon	Spain	600	22,4
5	ADM	Hamburg	Germany	580	21,6
6	Neste Oil	Porvoo	Finland	525	19,6
7	Ital Green Oil	Verona	Italy	360	13,4
8	Imperium Grays Harbor	Hoquiam, WA	USA	333	12,4
9	Oleoplan	Veranópolis (RS)	Brazil	333	12,4
10	ADM	Rondonópolis (MT)	Brazil	303	11,3
11	Infinita Renevables	El Ferrol	Spain	300	11,2
12	Green Earth Fuels of Houston, LLC	Galena Park, TX	USA	300	11,2
13	Granol	Cachoeira do Sul (RS)	Brazil	296	11,0
14	Louis Dreyfus Agricultural Industries, LLC	Claypool, IN	USA	293	10,9
15	ADM	Velva, ND	USA	283	10,6
16	ADM	Mainz	Germany	275	10,2
17	Bio-Oelwerk (Prokon)	Madgeburg	Germany	275	10,2
18	Biocapital	Charqueada (SP)	Brazil	261	9,7
19	Diester Industrie	Grand-Couronne	France	260	9,7
20	Diester Industrie	Grand-Couronne II	France	250	9,3
21	Diester Industrie	Le Meriot	France	250	9,3
22	Diester Industrie	Montoir/ST-Nazaire	France	250	9,3
23	Diester Industrie	Capelle-la-Grande	France	250	9,3
24	Diester Industrie	Bordeaux/Bassens	France	250	9,3
25	Cargill	Höchst	Germany	250	9,3
26	Vesta biofuels (Mercuria Group)	Brunsbüttel	Germany	250	9,3
27	Verbio Diesel Schwedt (Verbio Group)	Schwedt	Germany	250	9,3
28	Harvest Energy	Teesside	United Kingdom	250	9,3
29	Argos Oil	Rotterdam	Netherlands	250	9,3
30	Novaol (Diester Industrie International)	Livorno	Italy	250	9,3
31	Bionex	Badajoz	Spain	250	9,3
32	Bio-Oils	Huelva	Spain	250	9,3
33	Entaban	Bilbao	Spain	250	9,3
34	Skotan	Katowice	Poland	250	9,3
35	Ineos	Verdun	France	230	8,6
36	Agrenco	Alto Araguaia (MT)	Brazil	209	7,8
37	Diester Industrie	Sete	France	200	7,5
38	Biopetrol (Glencore)	Rostok	Germany	200	7,5
39	Cargill/Agravis	Wittenberg	Germany	200	7,5
40	Louis Dreyfus	Wittenberg	Germany	200	7,5

41	Verbio	Bitterfeld	Germany	200	7,5
42	Greenergy	Imminghan	United Kingdom	200	7,5
43	Mercuria Energy (Vesta Biofuels?)	Amsterdam	Netherlands	200	7,5
44	Eco Fox	Vasto	Italy	200	7,5
45	Ital Bi Oil	Bari	Italy	200	7,5
46	Mythen	Cosenza	Italy	200	7,5
47	Novaol (Diester Industrie International)	Ravenna	Italy	200	7,5
48	Oil B	Varese	Italy	200	7,5
49	Oxem	Pavia	Italy	200	7,5
50	Ecoil	Priolo	Italy	200	7,5
51	Abengoa	Huelva	Spain	200	7,5
52	Acciona	Bilbao	Spain	200	7,5
53	Entaban	El Ferrol	Spain	200	7,5
54	Entaban	Tarragona	Spain	200	7,5
55	Grupo SOS	Andujar	Spain	200	7,5
56	Saras	Cartagena	Spain	200	7,5
57	American Energy Producers, Inc.	Tina, MO	USA	200	7,4
58	FELDA IFFCO, LLC	Cincinnati, OH	USA	200	7,4
59	Caramuru	Ipameri (GO)	Brazil	198	7,4
60	Caramuru	São Simão (GO)	Brazil	198	7,4
61	Granol	Anápolis (GO)	Brazil	194	7,2
62	Petrobras	Candeias (BA)	Brazil	191	7,1
63	Olfar	Erechim (RS)	Brazil	190	7,1
64	JBS	Lins (SP)	Brazil	177	6,6
65	Owensboro Grain	Owensboro, KY	USA	167	6,2
66	Bioverde	Taubaté (SP)	Brazil	159	5,9
67	DP Lubrificanti	Aprilia	Italy	155	5,8
68	Biopetrol (Glencore)	Schwarzheide	Germany	150	5,6
69	Rheinische Bio	Neuss	Germany	150	5,6
70	Tecosol	Ochsenfurt	Germany	150	5,6
71	Cereal Docks	Vicenza	Italy	150	5,6
72	Biotel	Cuenca	Spain	150	5,6
73	Bioagra Oil	Tychy	Poland	150	5,6
74	Mercuria Energy (J&S)	Stobno	Poland	150	5,6
75	Mercuria Energy (J&S)	Skarbimierz	Poland	150	5,6
76	Rossi&MOL	Komarom	Hungary	150	5,6
77	Lake Erie Biofuels dba HERO BX	Erie, PA	USA	150	5,6
78	Binatural	Formosa (GO)	Brazil	143	5,3
79	Bsbios	Passo Fundo (RS)	Brazil	141	5,2
80	Delta American Fuel, LLC	Helena, AR	USA	133	5,0
81	EOP Biodiesel	Falkenhagen	Germany	133	4,9
82	Fiagril	Lucas do Rio Verde (MT)	Brazil	130	4,8
83	Camera	Ijuí (RS)	Brazil	127	4,7
84	Nord Ester (Daudruy)	Dunkerque	France	120	4,5

85	ADM	Leer	Germany	120	4,5
86	Comlube	Brescia	Italy	120	4,5
87	Western Dubuque Biodiesel	Farley, IA	USA	120	4,5
88	Green Valley Biofuels, LLC	Warrenville, SC	USA	117	4,3
89	Brasil Ecodiesel	Iraquara (BA)	Brazil	114	4,3
90	Brasil Ecodiesel	Porto Nacional (TO)	Brazil	114	4,3
91	Brasil Ecodiesel	Rosário do Sul (RS)	Brazil	114	4,3
92	Brasil Ecodiesel	São Luís (MA)	Brazil	114	4,3
93	Bsbios	Marialva (PR)	Brazil	112	4,2
94	Cooperbio	Cuiabá (MT)	Brazil	108	4,0
95	Comanche	Simões Filho (BA)	Brazil	106	4,0
96	Fertibom	Catanduva (SP)	Brazil	106	3.9
97	Biocarburantes CLM	Toledo	Spain	105	3.9
98	Biodiesel Aragon	Huesca	Spain	100	3.7
99	Biopaliwa (Elstar)	Malbork	Poland	100	3.7
100	Blue Sun Biodiesel, LLC	St. Joseph, MO	USA	100	3.7

List of largest recovery boilers

No.	Company	Location	Country	Capacity 1000 t/a	Capacity PJ/a
1	APP Riau	Kerinchi	Indonesia	7000	18.1
2	APP	Rizhao	China	7000	18.1
3	Aracruz	Guaiba	Brazil	6130	15.7
4	APP Hainan	Hainan	China	5000	12.9
5	Suzano Papel e Celulosa	Mucuri, Bahia Sul	Brazil	4700	12.9
6	Metsä-Botnia	Orion, Fray Bentos	Uruguay	4450	12.2
7	Wisaforest	Pietarsaari	Finland	4450	12.7
8	Celulosa Arauco y Constitución	Nueva Aldea	Chile	4400	11.3
9	Veracel	Eunapolis, Bahia	Brazil	4000	10.8
10	CMPC, Santa Fe	Nacimiento	Chile	3800	10.3
11	PT Riau Andalan Pulp & Paper	Kerinchi, Sumatra	Indonesia	3800	10.9
12	PT Riau Andalan Pulp & Paper	Kerinchi, Sumatra	Indonesia	3800	10.9
13	UPM-Kymmene	Kuusankoski	Finland	3600	10.7
14	Mondi	Syktyvkar	Russia	3560	10.6
15	Cenibra	Ipatinga	Brazil	3500	9.1
16	Oji Paper		China	3400	9.4
17	BSC		Brazil	3300	8.7
18	SCA	Östrand	Sweden	3300	8.7
19	PT Indah Kiat Pulp and Paper	Perawang, Sumatra	Indonesia	3300	9.5
20	PT Indah Kiat Pulp and Paper	Perawang, Sumatra	Indonesia	3300	9.5
21	PT Riau Andalan Pulp & Paper	Kerinci, Sumatra	Indonesia	3300	9.0
22	Enso-Gutzeit Oy	Kaukopää Mills	Finland	3300	8.9
23	Stendahl	Stendahl	Germany	3250	8.4
24	Södra Cell	Mönsterås	Sweden	3200	8.2
25	Metsä-Botnia	Joutseno	Finland	3150	8.2
26	PPT Kiani	Kalimantan	Indonesia	3150	8.4
27	Celulosa Arauco y Constitución	Valdivia	Chile	3100	8.3
28	Värö	Väröbacka	Sweden	3100	7.9
29	UPM-Kymmene, Kaukas	Lappeenranta	Finland	3100	7.5
30	OJS Ilim	Bratsk	Russia	3000	8.2
31	Oy Metsä-Rauma	Rauma	Finland	3000	7.5
32	Enocell Oy	Uimaharju Mills	Finland	3000	8.1
33	Howe Sound Pulp & Paper	Port Mellon, BC	Canada	3000	8.1
34	International paper	Campti, Louisiana	USA	2860	7.7
35	Weyerhaeuser	Valiant, OK	USA	2860	7.7
36	PT Wirakarya Sakti	Tebin Tinggi Mill, Jambi	Indonesia	2800	7.8
37	PT Indah Kiat Pulp and Paper	Perawang, Sumatra	Indonesia	2800	7.8
38	Repap, Skeena	Prince Rupert, BC	Canada	2770	7.7
39	Union Camp	Savannah, GA	USA	2721	7.7
40	Nippon Paper Industry	Iwakuni	Japan	2700	7.5
41	Alberta Pacific	Boyle, AL	Canada	2635	6.8

42	Celgar Pulp	Castlegar, BC	Canada	2610	7.4
43	Celgar	Castlegar, BC	Canada	2610	7.4
44	Skutskär	Skutskär	Sweden	2600	7.5
45	Kemi	Kemi	Finland	2600	6.8
46	CMPC	Laja	Chile	2500	6.6
47	VCP Jacareí Mill	Jacareí	Brazil	2500	6.9
48	Stora Paperboard	Gruvön	Sweden	2500	6.8
49	Alabama Pine Pulp	Perdue Hill, AL	USA	2500	6.8
50	Leaf River Forest Products	Leaf River	USA	2500	7.0
51	Naheola Cogeneration	Naheola, AL	USA	2450	7.1
52	Packaging Corporation of America	Valdosta, GA	USA	2400	6.9
53	Celbi	Figueira da Foz	Portugal	2400	7.3
54	Soporcell	Figuera de Foz	Portugal	2400	6.2
55	Oji Paper	Yonago Mill	Japan	2400	7.2
56	Oji Paper	Kasugai Mill	Japan	2400	7.2
57	Westvaco	Covington, VA	USA	2270	6.0
58	Weyerhaeuser Paper	Columbus, MS	USA	2270	6.0
59	ITT Rayonier		USA	2222	5.9
60	Stora-Enso Skoghal	Skoghal	Sweden	2200	5.6
61	Aracruz Celulose	Aracruz	Brazil	2200	6.9
62	Weyerhaeuser	Grande Prairie	Canada	2180	5.9
63	Weyerhaeuser	Oglethorpe, GA	USA	2177	5.9
64	PT Tanjungenim Lestari P&P	Musi, Sumatra	Indonesia	2120	6.1
65	Union Camp	Eastover, SC	USA	2100	5.8
66	Celulosa Nipo Brasileira	Ipatinga	Brazil	2050	5.7
67	Federal Paperboard		USA	2041	5.6
68	Georgia-Pacific	Crossett, AR	USA	2041	5.6
69	Weyerhaeuser	Valiant, OR	USA	2041	5.6
70	Weyerhaeuser		USA	2041	5.6
71	Aracruz C	Aracruz	Brazil	2041	5.6
72	Bowater, Calhoun	Calhoun, TN	USA	2041	5.6
73	Georgia Pacific	Woodland, ME	USA	2041	5.2
74	Nekoosa Papers	Ashdown, AR	USA	2041	5.8
75	Federal Paper Board	Augusta, GA	USA	2041	5.3
76	Potlatch	Cloquet, MN	USA	2040	5.6
77	Georgia Pacific	Brunswick, GA	USA	2040	5.9
78	Weyerhaeuser	Kamloops, BC	Canada	2040	5.9
79	Tiger Forest & Paper Group	Changsha, Hunan	China	2000	5.8
80	Sateri	Bahia Pulp	Brazil	2000	5.8
81	Burgo Ardennes	Virton	Belgium	2000	5.1
82	Arauco	Arauco	Chile	2000	5.4
83	Celimo (Aussedat Rey)	Saillat Vienne	France	1955	4.6
84	Aracruz, Guaiba (Riocell)	Gauiba	Brazil	1950	5.8
85	Zellstoff Pöls	Pöls	Austria	1900	5.3
86	Oji Paper	Kure	Japan	1900	5.8

87	Hokuetsu Paper Mills	Niigata	Japan	1900	5.5
88	Stora Enso, Kaukopää	Kaukopää	Finland	1900	4.2
89	Skutskär	Skutskär	Sweden	1900	5.4
90	Tembec	Témiscaming	Canada	1880	3.9
91	Union Camp	Savannah, GA	USA	1837	3.8
92	Celpac	Mininco	Chile	1837	5.5
93	Husum	Husum	Sweden	1815	3.5
94	Cariboo Pulp & Paper	Quesnec, BC	Canada	1810	3.5
95	Ence	Navia	Spain	1800	3.4
96	Domtar	Lebel Sur Quevillon	Canada	1800	3.4
97	Inland-Rome	Rome, GA	USA	1800	3.4
98	MacMillan Bloedel	Pine Hill, AL	USA	1800	3.4
99	Aracruz Celulose	Vitoria	Brazil	1800	3.4
100	Westvaco	Covingtona, AL	USA	1799	3.4

List of largest biomass gasifiers

No.	Company/Plant	Location	Country	Capacity MW_{th}	Capacity PJ/a
1	Lahti Energia	Lahti	Finland	160	4.0
2	Vaskiluodon Voima	Vaasa	Finland	140	3.5
3	Rüdersdorfer Zement	Rüdersdorf	Germany	100	2.5
4	Essent	Geertruidenberg	Netherlands	85	2.1
5	Electrabel (part of GDF Suez)	Ruien	Belgium	50	1.3
6	Södra Cell Värö Pulp Mill	Väro	Sweden	35	0.9
7	Agnion Technologies	Pfaffenhofen	Germany	33	0.8
8	Corenso United	Varkaus	Finland	32	0.8
9	Skive Fjernvarme	Skive	Denmark	32	0.8
10	Babcock & Wilcox Vølund	Kani-city, Gifu prefecture	Japan	12	0.3
11	NSE Biofuels	Varkaus	Finland	12	0.3
12	Ortner Anlagenbau	Oberwart	Austria	9	0.0
13	FICFB Güssing	Güssing	Austria	8	0.2
14	Babcock & Wilcox Vølund	Yamagata	Japan	8	0.2
15	Chalmers Technical University	Göteborg	Sweden	4	0.1

List of pellet mills under planning, capacity at least 1 PJ.

The list is not comprehensive.

No.	Company/Project	Location	Country	Capacity 1000 t/a	Capacity PJ/a
1	Suzano Energia Renovavel x3	Maranhão	Brazil	1 000	17.0
2	Biomass Secure Power	Baton Rouge, LA	USA	1 000	17.0
3	German Pellets	Tyler, TX	USA	550	9.4
4	Protocol Biomass	Ontario	Canada	500	8.5
5	Franklin Pellets	Franklin, VA	USA	500	8.5
6	Enviva LP	Courtland, VA	USA	500	8.5
7	Enviva LP	Northampton County, NC	USA	500	8.5
8	Enviva LP	Wiggins, MS	USA	500	8.5
9	Enova Energy Group	Edgefield County, SC	USA	450	7.7
10	Enova Energy Group (First Georgia BioEnergy)	Waynesville, GA	USA	450	7.7
11	Enova Energy Group	Warrenton, GA	USA	450	7.7
12	Canadian Bio Pellets	Ingleside	Canada	450	7.7
13	General Biofuels Georgia	Sandersville, GA	USA	440	7.5
14	Point Bio Energy	Baton Rouge, LA	USA	400	6.8
15	F.E. Wood & Sons	Baldwin, ME	USA	350	6.0
16	Fram Renewables	Lumber City, GA	USA	350	6.0
17	Westervelt Renewable Energy	Aliceville, AL	USA	309	5.3
18	Zilkha Biomass Energy	Selma, AL	USA	275	4.7
19	Biomass Secure Power	Vancouver Island, BC	Canada	250	4.3
20	Pacific Bioenergy	Kitwanga	Canada	250	4.3
21	Pacific Bioenergy	Kitwanga	Canada	250	4.3
22	Fulgrum Fibres	Augusta, GA	USA	200	3.4
23	Miktech	Ristiina	Finland	200	3.4
24	Woodlands Resources	Meigs, GA	USA	165	2.8
25	General Biofuels Canada	Terrace	Canada	150	2.6
26	New Forest Industries	Quebec	Canada	125	2.1
27	Atikokan Renewable Fuels	Ontario	Canada	120	2.0
28	Beaver Wood Energy	Fair Haven, Vermont	USA	110	1.9
29	Highland Biofuels	Lexington, Kentucky	USA	100	1.7
30	SEGA Biofuels	Nahunta, GA	USA	100	1.7
31	Graanul Invest		Baltics	100	1.7
32	Wagner Ontario Forest Management	Ignace, ON	Canada	85	1.4
33	Varn Wood Products	Hoboken, GA	USA	80	1.4
34	Whitesand First Nation	Armstrong, ON	Canada	80	1.4
35	KD Quality Pellets	New Liskeard, ON	Canada	75	1.3
36	Wawasund Group	Greenstone, ON	Canada	67	1.1
37	Viridis Energy	Monte Lake, BC	Canada	60	1.0

List of ethanol mills under planning, capacity at least 1 PJ

The list is not comprehensive.

No.	Company/Project	Location	Country	Capacity Ml/a	Capacity PJ/yr
1	Poet	Emmetsburg, Iowa	USA	473	10.0
2	Montana Advanced Biofuel	Great Falls, Montana	USA	435	9.2
3	Vivergo Fuels (BP, DuPont, ABFuels joint venture)	Hull	United Kingdom	420	8.9
4	Coskata	undisclosed	USA	379	8.0
5	Bioethanol	North Killingholme	United Kingdom	250	5.3
6	Vireol	Grimsby	United Kingdom	200	4.2
7	GeneSyst U.K.		Malta	180	3.8
8	Mascoma	Kinross, MI	USA	151	3.2
9	BP Biofuels	Highlands County, FL	USA	136	2.9
10	Canabrava	Rio de Janeiro state	Brazil	120	2.5
11	Verenium		USA	114	2.4
12	Abengoa		Brazil	100	2.1
13	Abengoa Bioenergy	Hugoton, KS	USA	95	2.0
14	Poet	Emmetsburg, IA	USA	95	2.0
15	Louisiana Green Fuels	Lacassine, LA	USA	95	2.0
16	GeneSyst U.K.		Malta	90	1.9
17	Range Fuels	Soperton, GA	USA	76	1.6
18	Bluefire	Fulton, MS	USA	72	1.5
19	Vinema Multióleos Vegetais	Rio Grande do Sul	Brazil	69	1.5
20	Vinema Vegetais	Rio Grande do Sul	Brazil	69	1.5
21	Iogen	Shelley, Idaho	USA	68	1.4
22	CEG Plant Goswinowice	Goswinowice	Poland	60	1.3
23	Green Future Innovations (ITOCHU, JGC joint venture)	Isabela	Philippines	54	1.1
24	BEST	Crescentino	Italy	51	1.1

List of biodiesel plants under planning, capacity at least 1 PJ

The list is not comprehensive.

No.	Company/Project	Location	Country	Feedstock	Capacity 1000 t/a	Capacity PJ/a
1	Indian Railways	Tondiarpet	India	Not known	6 900	257
2	Indian Railways	Raipur	India	Not known	6 900	257
3	Brasil Eco Energia		Brazil	Soybeans	734	27.4
4	Canadian Bioenergy - Northern Biodiesel	Lloydminster, Alberta	Canada	Canola	233	8.7
5	ADM	Lloydminster, Alberta	Canada	Canola	233	8.7
6	BioStreet Canada	Vegreville, Alberta	Canada	Oilseed	209	7.8
7	Great Lakes Biodiesel	Welland, Ontario	Canada	Multi-feedstock	150	5.6
8	Bioversel Sarnia	Sarnia, Ontario	Canada	Multi-feedstock	150	5.6
9	Four Rivers Bioenergy	Wilton	United Kingdom	Used cooking oil, virgin soy and rapeseed oil	120	4.5
10	BIOX Corp.	Bayonne	Canada	Waste grease and oil	88	3.3
11	TRT-ETGO	Bécancour, Quebec	Canada	Vegetable oil	88	3.3
12	Viridis Fuels	Oakland, CA	USA	Used vegetable and animal fats	67	2.5
13	Kyoto Fuels Corp	Lethbridge, Alberta	Canada	Multi-feedstock	58	2.2
14	Argent Energy	Motherwell	United Kingdom	Tallow and cooking oil	44	1.6
15	Methes Energies Canada	Sombra, Ontario	Canada	Multi-feedstock	44	1.6
16	Biocardel Quebec.	Richmond, Quebec	Canada	Multi-feedstock	35	1.3