BIOMASS FUELLED COMBINED HEAT AND POWER -SITUATION IN THE UK AND THE NETHERLANDS

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ABSTRACT: Combined Heat and Power (CHP) is the simultaneous generation of usable heat and power in a single process. Despite its obvious advantages in terms of increased efficiency when compared to a single heat or power generation unit, there are a number of technical and economic reasons that have limited their selection. Biomass resources can be, and actually are used as fuel in CHP installations; however several hurdles have to be sorted beforehand, among the most important is the fact that biomass energy sources are not as energy intense as conventional CHP fuels. The ultimate outcome is a limited number of CHP units making use of biomass as fuel. Even fewer CHP units use bioliquids (e.g.: fast pyrolysis biomass liquids, biodiesel and vegetable oil). The Bioliquid-CHP project is carried out by a consortium of seven European and Russian complementary partners, funded by the EU and by the Federal Agency for Science and Innovation of the Russian Federation. The project aim is to develop microturbine and internal combustion engine adaptations in order to adjust these prime movers to bioliquids for CHP applications. This paper will show a summary of the current biomass CHP installations in the UK and the Netherlands, making reference to number of units, capacity, fuel used, the conversion technology involved and the preferred prime movers. The information will give an insight of the current market, with probable future trends and areas where growth could be expected. A similar paper describing the biomass CHP situation in Italy and Russia will be prepared in the near future.

INTRODUCTION

This report will provide a brief description of the biomass fuelled CHP situation in the United Kingdom and the Netherlands based on number of units, capacity, fuel used, the conversion technology involved and the preferred prime movers.

Combined Heat and Power (CHP) is the simultaneous generation of usable heat and power in a single process and offers increased efficiency over conventional (separated) power and heat generation forms. The term biofuel is referred to as solid (bio-char), liquid (ethanol, vegetable oil and biodiesel) or gaseous (biogas, biosyngas and biohydrogen) fuels that are predominantly produced from biomass [1].

Figure 1 shows the infrastructure concerned with CHP from biomass.

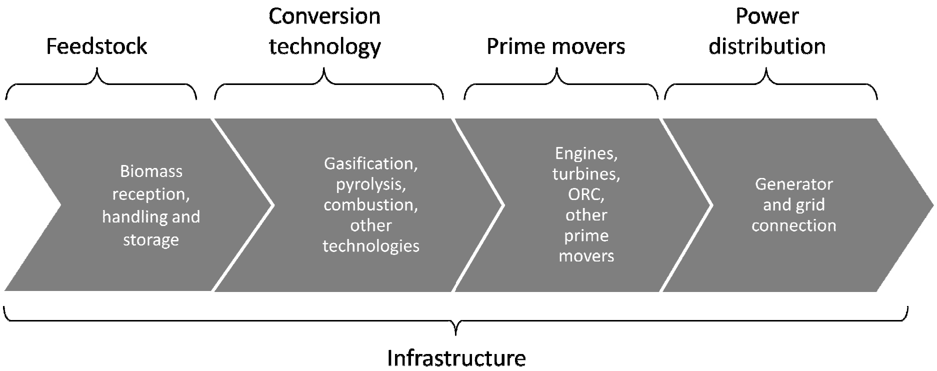

Figure 1. Infrastructure involved in Combined Heat and Power (CHP) from biomass

As a whole, biomass derived fuels are often criticised because of issues related to Carbon neutrality, as it is widely accepted that the production and transportation stages of biomass does add to the greenhouse gas effect. The extent in which a particular biomass source has an impact on the emissions balance is still subject to debate.

There are concerns that the need for biofuels may displace the native ecosystem or established food cropland. Increases in food crop productivity and yields, together with second-generation biofuels (non-food based crops) will overcome this issue.

The main advantage of CHP is the simultaneous production of heat and power with increased efficiency. The use of biomass adds benefits to the already advantageous situation, in terms of potential for reduced CO_2 emissions, security of supply and reduced energy prices.

PRIME MOVERS

Engines

Interest in engines powered by alternative energy sources peaks when oil prices are high and declines when oil prices are low, thus the main driver so far has been economic pressure.

However, increased awareness of CO_2 emissions has created a new level of consideration in which the use of biomass based fuels is seen as a must. Engines, because of their proven adaptability, reliability and efficiency are often seen as the preferred prime movers for biomass to energy applications.

Fuel quality is a major issue, with attention needed in dealing with lower heating value, high viscosity, particulates, biomass stability, low temperature properties, acidity and consistency. This has the effect of de-rating the engine output.

Engines are the preferred option as prime movers for small scale biomass CHP systems. Their benefits can be summarized as being highly efficient (when compared to turbines, Stirling engines and other prime movers), offer a degree of fuel flexibility and their robustness.

Internal combustion engines can be bought as an individual piece of equipment or as a package, either by the manufacturer or by resellers. Some of the most active manufacturers are GE, Caterpillar, Wärtsilä and MAN. Among the UK resellers are Edina, Ener-G, Baxi group and Cogenco.

Turbines

The selection of small scale (<1000kWe) turbines as prime movers for CHP is limited. At this scale most turbines have only one moving part: turbine, compressor and generator are in a single shaft and some use air bearings, thus the main advantages of turbines over engines are their compact size and low maintenance cost. A lower airborne emission when compared to engines is another advantage of turbines.

Similar to engines, the turbine efficiency will be negatively affected when fed by a lower heating value fuel, especially when at partial loads.

Several companies such as Capstone, Elliott, Ingersoll Rand, Turboden and Turbec are experienced in turbines running on biomass, although their products are not yet still available for the consumer mass market [2]. Bowman Power is a UK company that specialises in fitting current/existing engines with turbocompounding technology, this is, a turbine to recover energy from the exhaust system and provide additional power. They already support solutions running on diesel / biofuel and biogas [3].

Conventional Steam Turbines

Although a robust and well known technology holding the majority shares in power generation, conventional steam turbines tend not to be efficient at scales below 50MWe [4]. Some examples of steam turbines using biomass are shown as reference only.

Organic Rankine Cycle (ORC)

The ORC cycle is based in a closed Rankine cycle using a suitable low boiling point organic fluid. The vaporized organic fluid powers the turbine that drives a directly coupled electric generator. The exhaust gases are then condensed (producing hot water) and pumped to the evaporator where the cycle starts over again. Biomass can be burnt in the combustor and hot thermal oil is used as a transfer medium. There are commercial units in the range of 300 to 1200kWe, which, under the appropriate circumstances, could be economically attractive in many EU countries [5].

MARKETS

Current CHP Use in Europe

Large utilities generating electricity in a centralized manner are the most economically attractive way to produce energy currently.

The liberalization of the energy markets in Europe [6,7] has brought different levels of regulation within each EU country, driven by energy prices, security of supply and environmental concerns. Is it in this dynamic market where biomass CHP has to take an active role.

The document “Combined Heat and Power Developments in Europe” (Energy Business Report, 2007) recognizes that about 10% of all generated electricity in the EU comes from CHP, the majority of which are in the industrial sector. Growth is expected to be in the industrial sector until 2010, and in the domestic micro-CHP market after 2010.

The 2003 Biomass Cogeneration Project (BIOCOGEN) study [8] shows the proportion of CHP for the participants countries for 1999.

Table 1. Proportion of CHP as a share of national power production

Country	Share (%)
Netherlands	40%
UK	6%

The considerable difference between the Netherlands and the UK can be explained by the promotion of CHP through policy incentives that helped the development of CHP installations. With the market liberalization these incentives were removed from year 2000 on.

Accounting for all applications, capacity and technologies, the CHP potential was estimated to be of about 30%. The sector disaggregation for the market (1999) resulted in a marked dominance for the industrial and district heating sectors representing 94% of the installed capacity. The remaining percentage was allocated to the commercial sector, while the domestic figures were almost irrelevant.

The Combined Heat and Power Developments in Europe report states that CHP in the Netherlands is mainly gas fired. The industry sector accounts for almost half the electricity generation (48%), while district heating shares 27% followed by the horticulture industry with 12% and refineries with 6%. The rapid growth that started in 1980 somehow slowed down and virtually halted in 2000. This is a consequence of the market liberalization, by which electricity prices fell. Gas prices also rose, leaving CHP unable to match the electricity price offered by other power generators. The microgeneration sector (<20kWe) is still underdeveloped in the Netherlands and could represent a potential market of 6.5GWe by 2020. The Dutch government has expressed its support for small scale CHP installations due to the environmental benefits it delivers; however, the few incentives currently in place provide limited benefits to small industrial and commercial applications, such as tax breaks in the initial investment.

CHP in the UK grew significantly up to year 2000, however from this year the tendency stopped. Industrial applications account for 90% of all UK installed capacity, 75% of which are located in the oil, chemical paper and food/drink industries. Natural gas is the main fuel for CHP in the UK. District heating is not developed in the UK, where there is a preference for gas fired household size wet heating systems. This opens the opportunity for micro-CHP systems to be installed in potentially up to 18 million households [9]. There is a wide range of support schemes available for small scale CHP in the UK, as long as it fulfils the Good Quality CHP criteria. Incentives range from Enhanced Capital Allowances (ECA), Climate Change Levy and VAT reductions for domestic size CHP.

Current Biomass Fuelled CHP in Europe

The BIOCOGEN survey showed where there is existing relevant country by country experience using biomass cogeneration. Table 2 was adapted to reflect the Bioliquid-CHP participant countries and conceals the different scales/sizes and technologies in use or the demonstration and trial plants.

Table 2. Summary of existing biomass cogeneration applications for partner countries

Country	Waste	Sewage	Agro	Wood	Pulp and paper	District heating	Other areas of interest
Netherlands						Yes	Individual buildings, leisure industry
UK		Yes		Yes			Individual buildings, food industry

The BIOCOGEN survey concluded that the availability of biomass materials on site was important for biomass cogeneration. Many of these sites make use of heat as an energy source. Thus, opportunities for installing biomass cogeneration in sites without the feedstock or with related activities are limited.

The Netherlands has a better developed district heating network when compared to the UK that could be, in principle, target for biomass based CHP schemes. The Netherlands does have a larger share of using biomass in anaerobic digesters when compared to the remaining partner countries in the scale up to 1000kWe.

In the UK sewage treatment plants and the wood industry are seen as the preferred targets for biomass based CHP systems.

The general European picture shows that the district heating, waste industry (including sewage and landfill gas) and the wood industry are biomass CHP users and will become more established candidates for CHP in the future. All three sectors currently make use of the conversion technologies and prime movers subject of this study. All three sectors can produce bioliquids for CHP applications.

In terms of the wood processing industry, it is clear that the use of biomass cogeneration already exists in this sector. The two main reasons being biomass availability (as waste) and the need for heat and power. New technologies and strategies are also in the line for these established sources of energy.

The current use of CHP in district heating application varies widely between EU countries. The current situation in the UK shows a very small level of penetration of district heating, whereas in the Netherlands it is more common. The scope for developing new district heating schemes and/or retrofitting existing schemes with cogeneration plant is certainly an area of much interest.

NL Situation-Current Use of Biomass CHP

The situation in the Netherlands is biased towards the use of CHP coupled to anaerobic digestion in terms of number of units. Taking into account that anaerobic digestion is the dominant conversion technology, it is not a surprise food and farm waste (including manure) is the preferred feedstock as shown in Figure 2.

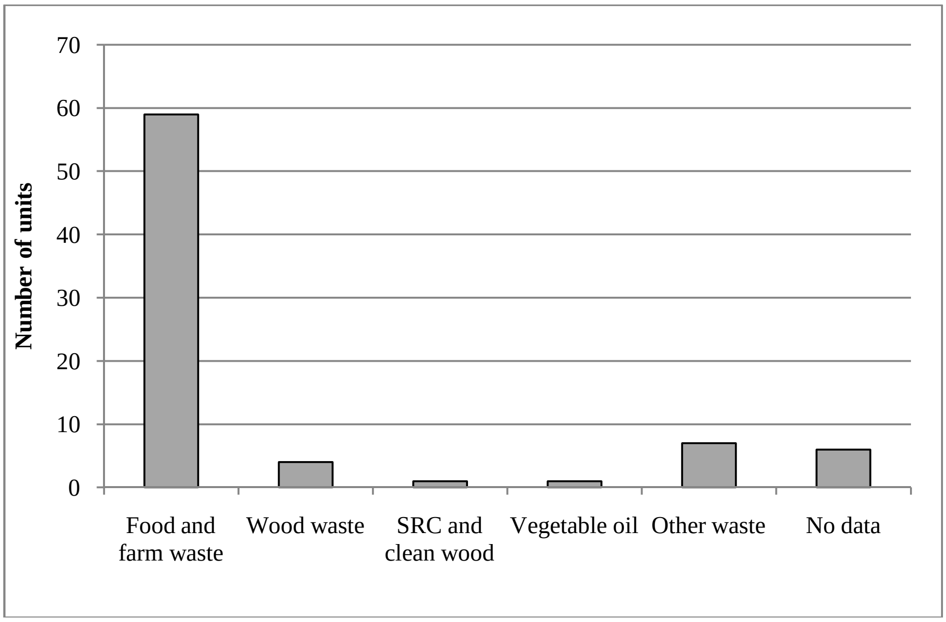

Figure 2. Biomass CHP in the Netherlands. Number of units organized by fuels used

Engines have been the preferred choice in the Netherlands as prime movers, as shown in Figure 3 below:

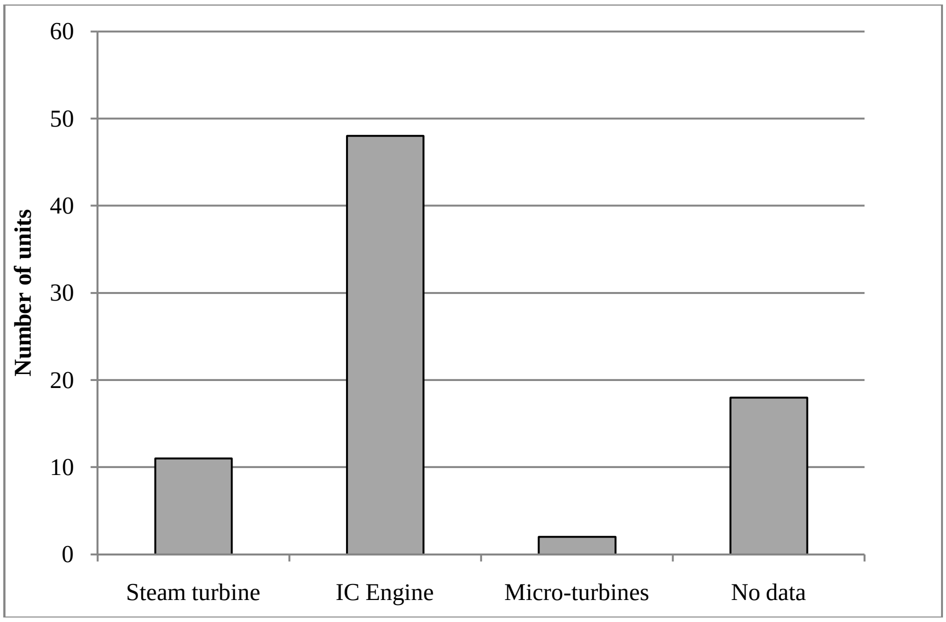

Figure 3. Biomass CHP in the Netherlands. Number of units organized by prime movers

Figure 4 shows the dominance of anaerobic digestion above other conversion technologies in the Netherlands:

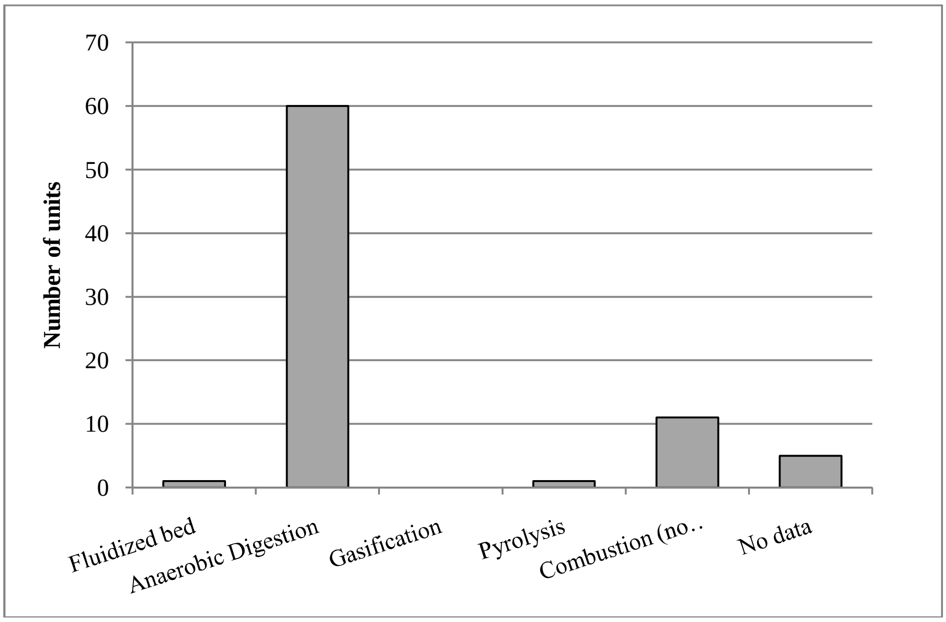

Figure 4. Biomass CHP in the Netherlands. Number of units organized by conversion technologies

Units either below 400kWe or larger than 1000kWe comprise the majority (65%) of the Netherlands market. The spread of size present in the Netherlands can be seen in Figure 5 below:

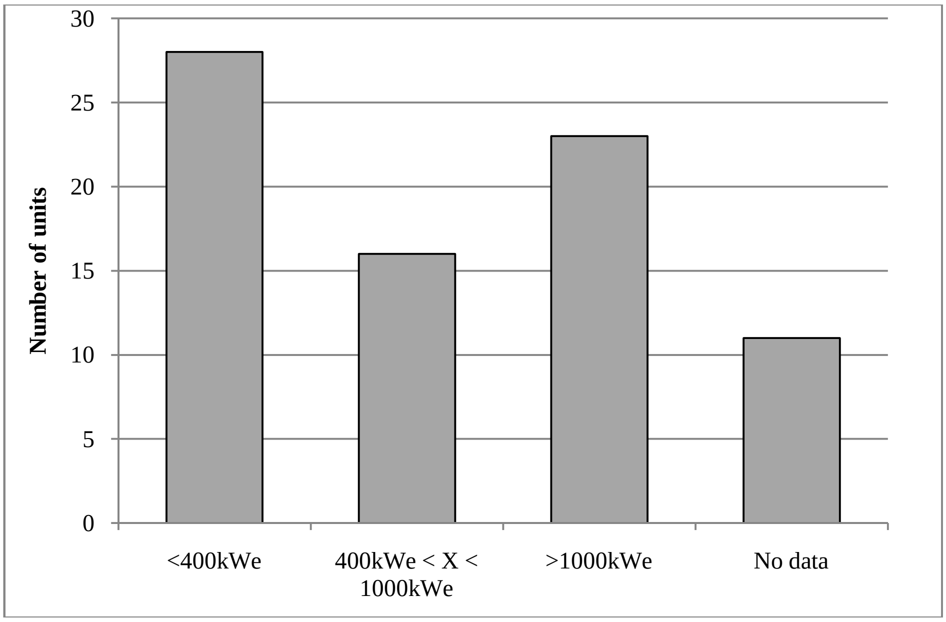

Figure 5. Biomass CHP in the Netherlands. Number of units organized by size range

Summarizing, in the Netherlands the situation for biomass CHP comprises a digester feed by farm and food waste coupled to an engine with less than 400kWe capacity.

UK Situation-Current Use of Biomass CHP

According to the 2008 UK Energy Digest [10] 3.7% of the fuels used for CHP generation in 2008 were renewable, i.e. sewage gas, other biogases, municipal waste and refuse derived fuels, resulting in the generation of 838GWh of electricity and 1,566GWh of heat. The same source established that by 2008 there were 344MW of electric capacity and 506MW of thermal capacity installed.

Figure 6 below shows that the increase in CHP generation from renewables for the period up to 2007 is slow, with an average of two percent increase for heat since 2001 and 7.43% increase for electricity. Year 2008 saw a jump in both heat and power generation in CHP mode from renewable energy sources with an increase of 69% for heat and 28% in power relative to the previous year.

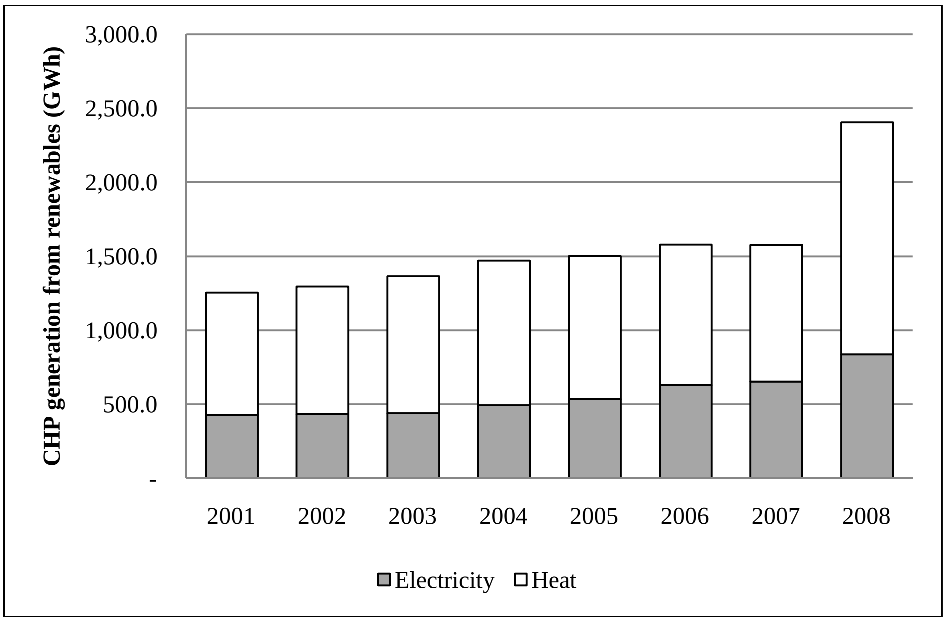

Figure 6. CHP generation from renewable in the UK

Regarding the UK installed biomass CHP capacity, the research showed that large projects over 1MWe dominate the UK's biomass CHP scene with a share of 58% followed by schemes smaller than 400kWe.

Most installations make use of engines as prime movers as shown in Figure 7.

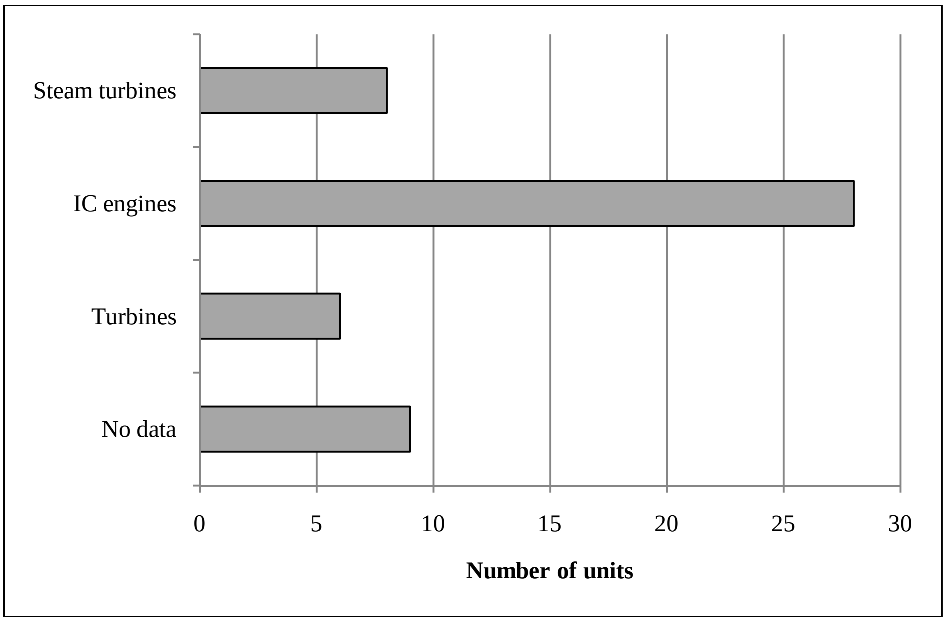

Figure 7. Biomass CHP in the UK. Number of units organized by prime movers

Figure 8 shows that Short Rotation Coppice (SRC) and clean wood are the most used feedstock for biomass CHP in the UK, whereas food and farm waste, wood waste, recovered vegetable oils and other waste are used in fewer units.

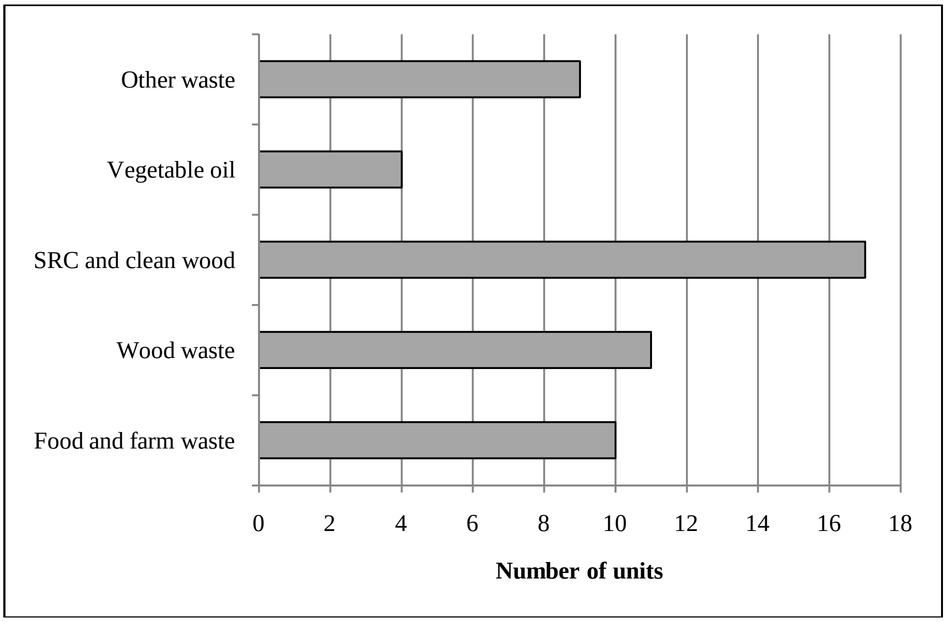

Figure 8. Biomass CHP in the UK. Number of units organized by fuels used

Figure 9 shows that gasification is the main technology in the UK CHP biomass market. Anaerobic digestion has not taken a significant proportion of the UK's despite its acceptance and use across Europe.

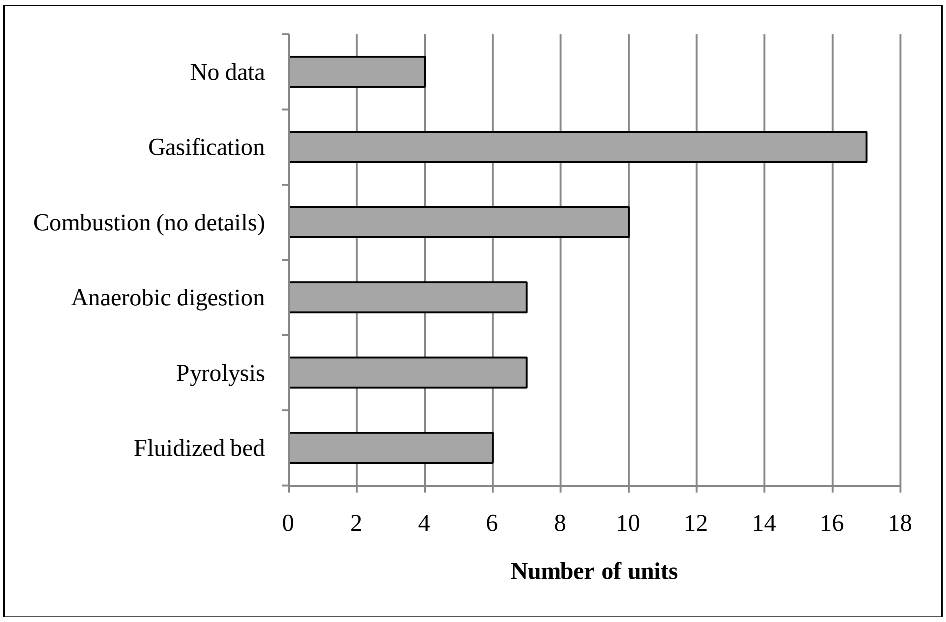

Figure 9. Biomass CHP in the UK. Number of units organized by conversion technologies

The size distribution of the UK biomass CHP units is shown in Figure 10, where roughly large schemes above the 1000kWe and small schemes of less than 1000kWe output are both present in approximately similar numbers.

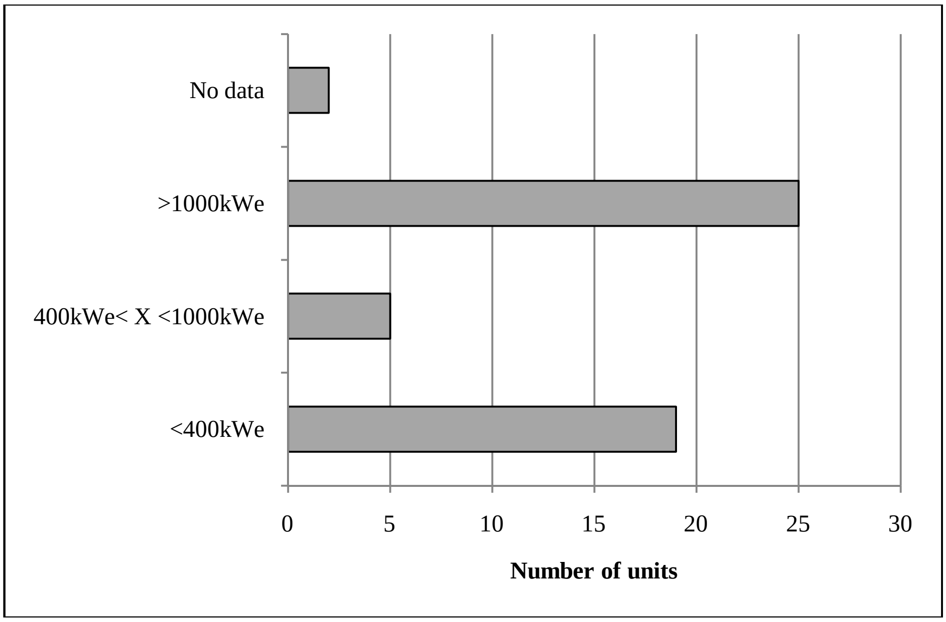

Figure 10. Biomass CHP in the UK. Number of units organized by size range

The UK experience with biomass CHP can be summarized as varied. Most systems are for making use of SRC and clean wood, however, the waste market as a whole is also present. Gasification tends to be the preferred conversion technology coupled with and engine as prime mover.

The CHP prospect in Europe has suffered as a consequence of the liberated market. One of the main reasons for this is that the fuel for many new CHP installations is Natural Gas, and this fuel has increased price steadily over the past years. At the same time the electricity production cost has seen reductions, thus constraining the competitiveness of CHP applications. There is also an element of uncertainty because of the changing regulations for CHP, which adds to the unsure future picture. There has been a concerted EU effort in trying to implement CHP incentives throughout the region including financial measures such as grants, feed-in tariffs and tax exemptions, legal provision to analyse the suitability of CHP above certain capacity, and the legal requirement to provide access to the electricity network for CHP installations. Nevertheless, it is expected that CHP will grow slightly from the current 10% to 14% by 2030.

Future of Biomass in Europe

In theory, there should be an abundance of biomass ready available to be used in the future for CHP applications. In practice, many barriers hinder the availability of biomass. There is a well-known lack of information about biomass and biomass waste. Very few countries keep good records of biomass for energy, sewage, waste wood and biomass waste related quantities. On the topic of energy crops, their potential is considerable and should be approached with caution as it will be very much policy dependant and country specific.

Assessing biomass potential is not an easy task, not just because of the lack of information but also because of the variety of methodologies for assessing such potential. The Biomass Energy Europe project (BEE) report in 2008 [11] recognizes at least three different approaches in order to estimate the biomass potential of Europe and/or union countries: resource-focused, demand-driven and wood resources balance. While a resource-focused analysis looks at “the total bioenergy resource base and the competition between different uses of the resources (supply side)", the demand driven analysis deals with "the competitiveness of biomass-based electricity and biofuels, or estimates the amount of biomass required to meet exogenous targets on climate-neutral energy supply". The wood resource balance is a novel approach that is "based on available production and trade statistics and a consumption analysis which can be based on available statistics and is strongly supplemented with field research".

The BEE reports the following for the EU25 area (see Table 3):

Table 3. Europe biomass estimated potential (EJ/annum). BEE 2008 report

Study	Scenario	2020	2030
EEA 2006	-	9.9	12.3
Ericsson & Nilsson 2006	Low biomass harvest	4.4	5.3
	High biomass harvest	n/a	7.6
De Wit & Faaij 2008	Average		16.5
Ganko et al 2008	S1	7.2	
	S2	4.7	
Siemons el al 2004	-	8.8	
Tharan et al 2006	Environmental +	9.0	
	Current policy	14.2	

The study goes to explain the reasons for the disparity in the estimations, namely the inconsistent and ambiguous definition of potential, lack of current biomass data, different methods for estimating potential and ambiguous definitions of factors that influence the estimation such as land use, proportions for food production etc.

Nevertheless, it is noticeable that the resources increase over the period from 2020 to 2030. This could be either for increased productivity and yields or changes in policy or a combination of both. The predicted increase travels from 20% (Ericsson & Nilsson 2006) up to 24% (EEA 2006).

When compared to the 2010 or current estimations, then the growth is more clear with an increase from 14% (Siemons el al 2004) to 41% (Tharan et al 2006) up to 2020 and 56% for the entire period between 2010 to 2030 (EEA 2006). In Table 4 is shown a summary for the UK and the Netherlands.

Table 4. Bioliquid-CHP country partner's biomass estimated potential (PJ/annum). European Environment Agency Technical Report No10/2008 [12]

Country	2020	2030
The Netherlands	40	54
United Kingdom	317	576

As it can be seen, the biomass availability is expected to increases for both countries. In terms of growth rates for the ten year period, the UK is predicted to see the largest increase with 82% growth, while the Netherlands is not far behind with 35%.

Future of Biomass Fuelled CHP in Europe

Several studies have highlighted the important role that CHP will play in the future of Europe. Early assessments in 2004 [see 4] estimated that the only way to reach the cogeneration target set by the EU from 9% in 1997 to 18% in 2010 was including micro-generation (less than 1Mwe) in the CHP mix, albeit with a range of fuels from Natural Gas, biomass and waste. In the same study biomass based CHP was expected to increase its presence from 2GWe in 2000 to 20GWe in 2020, of which it is assumed small scale biomass fuelled would contribute with 3.6GWe.

BIOCOGEN reported in 2003 that the contribution of biomass to cogeneration could be of 11GWe by 2010 with an additional 9GWe for 2020. The forecast shows that the domestic sector could grow to 28% of the EU cogeneration capacity by 2020 from virtually zero contribution in 1999, however, this can only be possible if technological improvements and policy changes are implemented.

The Cogeneration Observatory and Dissemination Europe [13] project (CODE) funded by the European Commission has made available in 2010 its first report on the potential for CHP in the EU with information supplied by the member states. In here it is envisaged that an additional cogeneration capacity of 122GWe is economically feasible and which could be in operation in by 2020. Although this figure encompasses a wide spectrum of capacity, range of applications and fuels, biomass is expected to make a contribution. If a assumption of about 8% of total growth as biomass based CHP, then 10GWe could be attributed to biomass, of which 2GWe could be in the capacity scale of below 1000kWe.

Biomass and biomass CHP do have several drawbacks, one of which has already been discussed in this document: the lack of reliable information. This becomes a barrier because it causes uncertainties that are normally addressed as economic risk, thus financers expect to recover a good proportion of the investment in a short period of time and at above average return rates.

Similarly, biomass markets are not mature and stable as other commodity fuels, thus adding to the perception of small and financially unattractive business propositions. The high capital cost of biomass CHP and elevated cost due to its inherited seasonal nature and low energy density limit the widespread use of biomass as fuels for CHP.

CONCLUSIONS

The use of biomass for Combined Heat and Power adds potential for further reduced CO_2 emissions, greater security of supply and reduced energy prices as main benefits.

The CHP prospect in Europe has suffered as a consequence of the liberated market and reduced electricity prices. Nevertheless, it is expected that CHP will grow slightly from the current 10% to 14% by 2030.

Accounting for all applications, capacity and technologies, the CHP potential in Europe is estimated to be of about 30%.

In the Netherlands, the rapid growth that started in 1980 somehow slowed down and virtually halted in 2000. CHP in the UK grew significantly up to year 2000, when its growth rate slowed down.

Compared with the UK, the Netherlands has a somewhat better developed district heating network that could be target for biomass based CHP schemes. The microgeneration sector (<20kWe) could represent a potential market of 6.5GWe by 2020.

In the UK sewage treatment plants and the wood industry are seen as the preferred targets for biomass based CHP systems.

CHP in the Netherlands favours anaerobic digestion in terms of number of units. Engines have been the preferred choice as prime movers and units either below 400kWe or larger than 1000kWe comprise the majority (65%) of the Netherlands market.

In the UK most installations make use of engines as prime movers, fed by SRC and clean wood. Schemes above the 1000kWe and small schemes of less than 1000kWe output are both present in approximately similar numbers.

Assessing biomass potential is not an easy task, not just because of the lack of information but also because of the variety of methodologies for assessing such potential. However, resources increase over the period from 2020 to 2030 for the majority of the studies reviewed.

Finally, different sources agree that the contribution of biomass to cogeneration could be of 11GWe by 2010 and 20GWe for 2020.

ACKNOWLEDGMENT

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