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CURRENT STATE AND FUTURE PERSPECTIVES OF BIOMASS IN THE EUROPEAN UNION: FOCUSING ON COMBINED HEAT AND POWER (CHP) APPLICATION

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ABSTRACT
Biomass is one of the Renewable Energy Sources (RES) that has a worldwide potential to be exploited, but, it seems not to be in the European Union (EU) countries, where the biomass potential is not fully manipulated. Bioheating and bioelectricity are the two applications of biomass which have a practical gap that still need specific enhancement in order to meet the Kyoto targets which are to increase the renewable energy share gross consumption up to 12% as well as to abate CO_2 emission by 2010. However, due to a lack of appropriate legislative tools and policies mainly in bioheating and inefficient of bioelectricity itself, Kyoto target is likely far to be achieved by the EU. Therefore, as far as this problem is concerned, implementation of cogeneration or so called combined heat and power (CHP) system is considered as among the way that could be taken to solve this problem. This is parallel to the Directive 2004/8/EC, 2004 that addresses about the advantages using this system which can increase the overall energy performance and reduce CO_2 emissions. In the future perspective of EU, possessing abundant of solid biofuels make the CHP system is definitely relevant to be run. In fact, it is not only in EU perspective but this concept can fortunately be generalized to the other regions all over the world based on their climate, land availability as well as national policies.

Keywords: *Biomass, Bioheating, Bioelectricity, Cogeneration/Combined Heat and Power (CHP)*

INTRODUCTION
In the near future, renewable energies are firmly deemed will dominate the world's energy supply system. The reason is at the same time very simple and imperative: there is no alternative [1]. Mankind cannot indefinitely continue to base on the consumption of finite energy resources particularly fossil fuels which will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. Instead of fossil fuels, renewable energy sources (RES) namely biomass, solar, geothermal, wind, ocean, as well as hydropower are constantly replenished and never run out. On top of that, renewable energies are also characterized as economical and clean technologies since the basic sources of these technologies are environmental based (i.e. wood, wind, wave, solar and etc.).

Basically, RES not only provide power, heat and transport fuels, but they also offer opportunities for a future way of living that embrace a sound development path. Realizing the matter of fact, European Union (EU) is among who is solemnly concern to exploit all the renewable energies potential. This is upon parallel to the EU goals which are in way combating the global climate change in respect to cut greenhouse gas emissions (GHGs), together with the need to improve the security and diversity of energy supply.

With regards to this matter, one of the main pillars of the EU strategy is to meet Kyoto protocol which are to increase renewable energy share gross consumption up to 12% as well as to cut CO_2 emission by 2010 [2]. In order to achieve this target, EU has yet assembled ambitious legislation, so called directives remarkably in order to promote and improve RES electricity [3], high-efficiency cogeneration [4], application of bio-fuels [5], and energy performance of building [6].

Nevertheless, it is a matter of concern that the policies and measures executed are not, so far, in line with the targets of 2010. The policies and measures currently in place seem likely to lead to a renewable energy share of approximately 9-10% by 2010 [7]. Therefore, the evaluation potential and progress of individual RES types for each member states are carried out. This can expectedly assist in recognizing which sort of renewable energy has the potential but still not entirely been manipulated. According to the annual growth rates between 1995 and 2001, it clearly states that the wind is far beyond the target and others (i.e. hydro, geothermal, and photovoltaic) are well in the expectation [8]. However, this scenario is not relatively same with biomass which its potential has not been fully exploited mainly in the EU [8]. Therefore, to meet the Kyoto protocol target, which is reasonable, specific support actions for biomass technology, has to be taken soon. There are promising advantages should be obtained by the EU in the near future, if once the Kyoto target is achieved primarily in the biomass context:-

(i) Improve the security and diversity of energy supply

The EU currently imports 50% of its energy needs, and it is projected to be inclined up to 70% with an increasing share for fossil fuels [9] (Fig. 1). If there is no action taken, for long term, it will severely affect the economy and politic of Europe. With fulfilling the target of Kyoto protocol especially for the lag behind technology such as biomass; this scenario can be certainly improved.

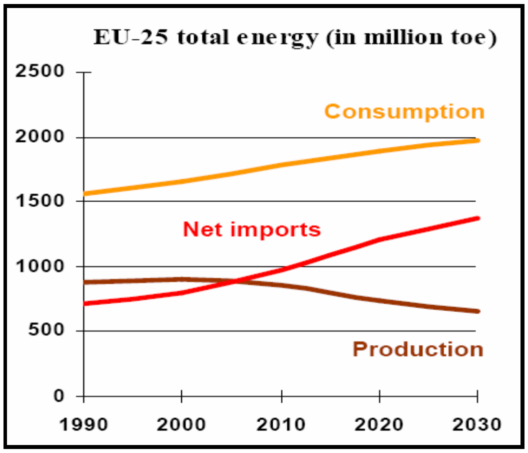

Figure 1: Total energy consumption of EU-25 between 1990 and 2030 [10]

(ii) CO_2 emission savings

Table 1 shows if the biomass application meets the Kyoto protocol target, it will emerge as the highest technology that can reduce CO_2 emission up to 176 Mt/year and 326 Mt/year by 2010 and 2020 respectively. The CO_2 released is equivalent to the amount of CO_2 absorbed by the biomass (photosynthesis) in the growing phase. Hence, it leads to almost zero emission of CO_2, and substantially can contribute to reach the targets of the Kyoto protocol which want to reduce the amount of CO_2 emission between 2010 and 2020 from 320 Mt/year to 728 Mt/year [8].

Table 1: Saving in CO_2 emissions (million tones) [8]

	2010	**2020**
Wind	99	236
Photovoltaic	2.2	24
Biomass	176	326
Hydro	23	35
Geothermal	5.8	15
Solar Thermal	14	92
Total RES	320	728
% of total EU 15 Greenhouses Gas (GHG) emission in 1990	7.6%	17.3%

(iii) Employment

Implementing biomass technology can as well create employment at much higher rates than other renewable energies technology. In fact, it significantly gives positive scenario towards rural development mainly by creating direct employment and by supporting related industries.

Table 2 : Employments [8]

	2010 jobs FTE	**2020 jobs FTE***
Wind	184,000	318,000
Photovoltaic	30,000	245,000
Biomass	338,000	528,000
Biofuels	424,000	614,000
Small Hydro	15,000	28,000
Geothermal	6,000	10,000
Solar Thermal	70,000	280,000

* *full time employment*

Above explanation is believed sufficient enough to justify why biomass has been chosen as a key subject to be discussed in this case study. Believe on its world-wide potentials which have not been fully exploited [11, 12], this case study will figure out which area in biomass technology particularly its applications (i.e. bioheating, bioelectricity and biofuels) that might have a gap for doing enhancement in route to meet Kyoto target. This case study firstly discusses the utilization of biomass applications by based on the previous and on-going associated R&D activities. At the end, the anticipating future trend and projection for the biomass is proposed specifically for the EU and generally for the world-wide perspective.

PRACTICAL GAP IN BIOMASS APPLICATIONS

Biomass is available in a variety of forms, such as vegetable oil, sugar and starch, ligno-cellulosics (wood) as well as wet biomass. These raw materials can then follow several conversion routes, using chemical, thermal or biological processes. Finally, biomass can be classified according to its end-use. As can be seen in Fig. 2, the main applications of biomass can be separated into three (3) which are biofuels, bioelectricity and bioheating.

Of these three applications, bioelectricity is considered having a huge potential in Europe, however, it is not yet utilized sufficiently which is only about 11.6% of the renewable electricity (Fig. 3) [1]. In order to promote the use of bioelectricity, a Directive has been proposed and objective to achieve 21% RES-E in 2010 has been set out [3]. Nevertheless, according to COM(2004)366 the overall target of 21% bioelectricity for EU15 in 2010 will not be met under current policies even under a scenario of reduced total electricity demand due to energy efficiency measures. Based on the current situation, it is likely that 18% to 19% will be produced, and this is partly explained by a poor performance of bioelectricity [13].

Basically, bioheating is a key market for biomass [8, 13, 10]. Indeed, it represents almost all renewable heat which is about 96.2% in 2002 (Fig. 3). However, several experts and associations have pointed out that there is a lack of appropriate legislative tools and policies to support its market development [8]. All in all, a directive on heat, for instance, stating national targets for renewable heat, would be welcome.

On biofuels side, thanks to new impulse given by European Directive regarding the promotion of bio-fuels which each member states was forced to consider liquid biofuels development in their country with indicative share is aimed to increase up to 5.75% by 2010 [5]. This basically contributes positive outcome towards biofuels evolvement. Now the EU focus is to develop second-generation biofuels type under BAP 2005. This type of biofuels is extracted from biomass resources and wastes, such as biodiesel, bioethanol and DME [14]**.** In fact to this age, there are lots of efforts put into this matter in terms of performing standard, legislative, policies, and research.

In route to reinforce the current legislative and policies, the new objectives for EU25, as illustrates in Fig. 4, has been proposed under Biomass Action Plan (BAP) (COM(2005)528) which comparable to meet Kyoto target. Again, it shows that bioheating acts as the largest market of biomass which has been targeted to increase as much as 27 Mtoe to 78 Mtoe in 2010, instead of only 48 Mtoe in 2003. Bioelectricity and biofuels, on the other hand, are respectively aimed to meet the target of 55 Mtoe and 19 Mtoe by 2010. Biomass technology will meet

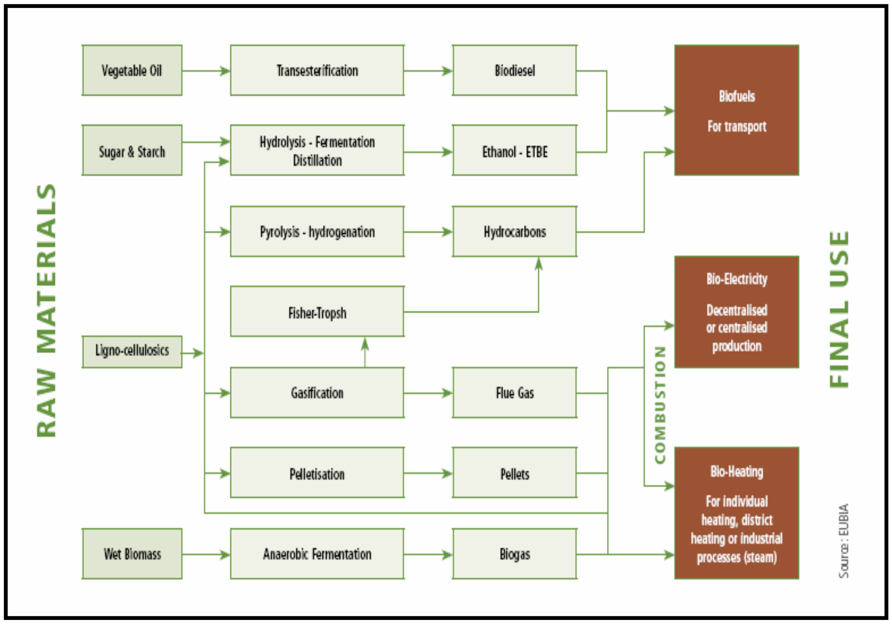

Figure 2: Main biomass routes

the target if the policies for renewable heat are improved, national plans based on the electricity directive are achieved, and the requirements of the biofuel directive are fulfilled [13].

As realizing the largest market of biomass is heat which is still not fully exploited due to some lacking in the legislative tools and national policies, additionally, the claiming of inefficient performance of current bioelectricity technology which is truthfully having the great potential to be manipulated, therefore, this case study will explore in perspective of how these both types of applications can lead biomass technology to achieve Kyoto target.

In respect to this, the best solution is via adopting the cogeneration system so-called combined heat and power (CHP) which can generate electrical (or mechanical) and useful thermal energy simultaneously. Therefore, under BAP the Commission has encouraged all the EU countries to implement CHP systems. In fact, by using this system, the overall energy efficiency can basically be increased, in extend to that, it can abate CO_2 emission, hence, fulfill the Kyoto target [4, 11, 12]. Basically the CHP systems can be classified into three categories; industrial cogeneration, heating cogeneration and agricultural cogeneration [4].

RECENT ADVANCES OF CHP UTILIZATION

The energy available in biomass may be utilized either by direct use as in combustion or by initial upgrading into more valuable and useful fuels such as charcoal, liquid fuels, producer gas or biogas. Fig. 5 gives a summary of the different options possible. Combustion is a well-established commercial technology with applications in most industrialized and developing countries and development is concentrated on resolving environmental problems, improving the overall performance with multi-fuel operation and increasing the efficiency of the power and the heat cycle [15, 16, 17). In this sense, increasing the overall energy efficiency and reducing CO_2 emission are the main goal in using CHP system (Fig. 6(a), and (b)) which is considered as the combustion oriented technology. Conventional power, on average, is only 35%-65% efficient of the energy potential is released as waste heat. More recent CHP system can improve this to 55%, excluding losses for the transmission and distribution of electricity. Through the utilization of the heat, the efficiency of CHP plant can reach up to 90% or more [15].

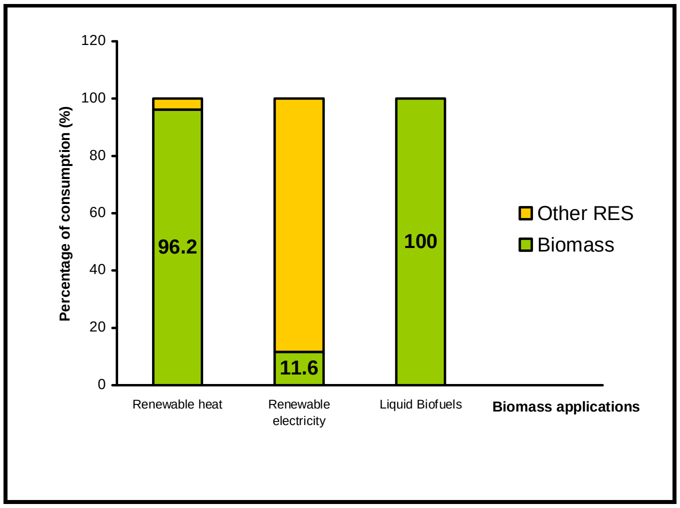

Figure 3: Percentage of consumption biomass applications for EU15 in 2002 [13]

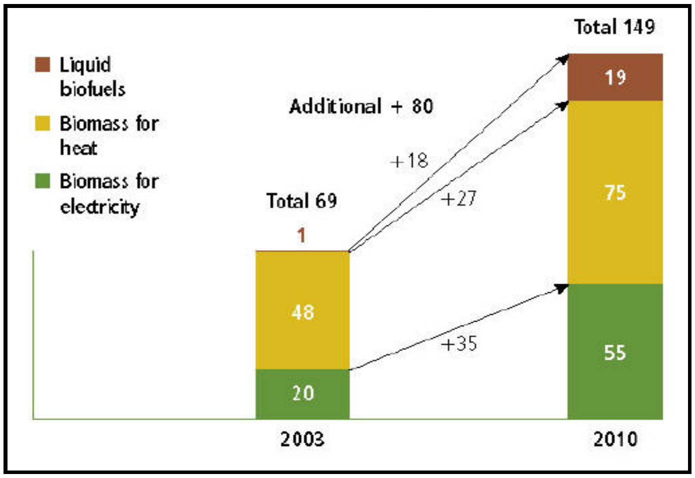

Figure 4: Target for EU25 according to the Biomass (Mtoe=millions ton oil equivalent) [14]

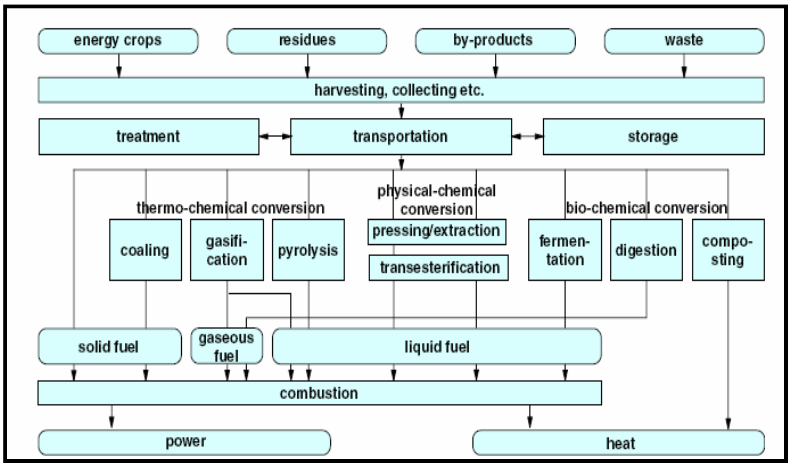

Figure 5: Possibilities to provide heat and power from biomass [18]

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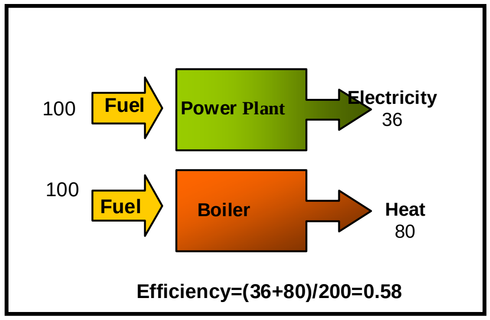

Figure 6(a): Separate production of electricity and heat [15]

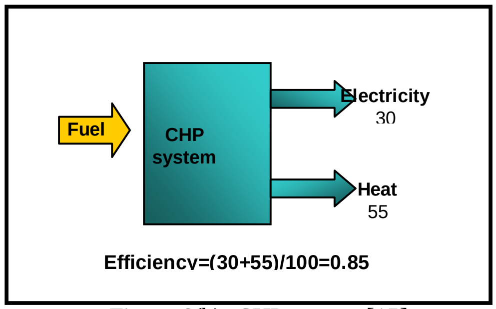

Figure 6(b): CHP system [15]

CHP is characterized as a mature and established technology, since its capability providing a reliable and cost-effective energy supply has been verified. In fact, this technology is excessively used on many thousands of area throughout the Europe, and supplied approximately 10% of both electricity generated and heat demand in the EU15 in 1999 [15].

Finland and Denmark are two European countries that own huge amount of biomass sources. These two countries implement CHP systems with burning straw and forest residues and it then undoubtedly offers great economic performance [14]. The dominance of CHP over direct electricity production in UK (Table 3) also illustrates that appropriate schemes are likely to be developed in response to specific support mechanisms. This is despite the fact that provision of heat does not count towards the UK government’s 2010 renewable target, although it will contribute to the government CHP capacity target, and the fact that there is no mechanism for certifying or rewarding the contribution of biomass-based heat projects in the UK at present [19].

Biomass resources and their characteristics are important to be taken into account particularly when dealing with combustion since it likely affects the process control, necessary combustion and flue gas cleaning technology [20]. For the CHP systems, the main biomass resource is solid biofuel which are wood and waste. According to the political goals formulated by national parliaments of members states within the European Union the contribution of solid biofuels within the energy system will increase in the years to come (Kaltschmitt, and Weber, 2006). Additionally, Table 4 shows that there are sufficient biomass resources available in the Union, and can expectedly satisfy the demands of an additional up to 80 Mtoe/year by 2010 without significant impacts on either to food production or forest products industries [14].

Table 5 shows a list of existing UK plants that generate electricity commercially from a variety of available biomass resources in UK (including wood and animal wastes, but excluding landfill gas, municipal waste and sewage sludge feedstocks). On the whole, it is not only in the UK, in fact by the EU itself is characterized having a huge potentials of solid biomass. By far the largest share of the existing potential is based on woody biomass. Compared to this the potential from energy crops and herbaceous biomass is considerably smaller [18]. Thus, implementing CHP systems supposedly not become a big deal for the EU, since their have resources.

The different markets for woody solid biofuels can be subdivided according to the effort to provide a solid fuel with clearly defined fuel characteristics (i.e. a standardized fuel) which are; (1) markets for solid biofuels with low variations of fuel properties (i.e. upgraded fuels like pellets and briquettes); (2) markets for biofuels with medium variations of fuel properties (i.e. processed fuels like wood chips), and (3) markets for biofuels with high variations of fuel properties (i.e. fuels like wood logs) (Fig. 7) [18]. In context of CHP systems, solid biofuels in market (1) and market (2) are typically used, and the most recent one which is being used is pellets.

Table 3: CHP plants in UK [19]

Station name	Developer	Capacity (MWe)	Technology	Fuel	Features/Comments
Winkleigh	Peninsula Power	23.00	Gasifier	Wood	wood fired—extensive integration with ethanol plant etc.
Sevenhampton	Roves Energy	2.50	CHP	Energy crops and forestry residues	
Frome	Charlton Energy	7.00	CHP	Sawmill residue	
Castle Cary	Bronaeoak	4.00	CHP gasifier		
Eccleshall	Eccleshall Biomass	2.20	CHP	Miscanthus	
Wilton	Sembcorp	30.00	Fluidised bed	Wood	
Lockerbie	Powergen	40.00		Wood/forestry residues	
Corpach	Arjo Wiggins	n/a	CHP	Wood	
Balcas	Balcas	2.7	CHP	Sawmill residue	Includes pelletising plant

Table 4: EU biomass production potential[42][14]

Mtoe	**Biomass consumption, 2003**	**Potential, 2010**	**Potential, 2020**	**Potential, 2030**
Wood direct from forest (increment and residues)	67[43]	43	39-45	39-72
Organic wastes, wood industry residues, agricultural and food processing residues, manure		100	100	102
Energy crops from agriculture	2	43-46	76-94	102-142
TOTAL	**69**	**186-189**	**215-239**	**243-316**

42 Sources: 2003 data from Eurostat; projections for 2010, 2020 and 2030 from European Environmental Agency, "How much biomass can Europe use without harming the environment", briefing 2/2005.

43 This figure includes 59 Mtoe of wood and wood wastes; 3 Mtoe of biogas; and 5 Mtoe of municipal solid waste.

Table 5: Existing UK biomass stations February 2004 [19]

Station name	Owner	Capacity (Mwe)	Technology	Fuel	Features/comments
England & Wales					
Elean Business Park*	EPR Ely Ltd	36.85	Vibrating grate	Straw	Natural gas support
Glanford Power Station (Fibrogen)	Fibrogen Ltd	16.70	Stoker grate	Poultry litter	
Thetford Power Station	Fibrothetford Ltd,	41.50	Stoker grate	Poultry litter	
Eye Power Station (Fibropower)	Fibropower Ltd	14.32	Stoker grate	Poultry litter	
Fawley Waste to Energy Plant	Shanks Chemical Services Ltd	8.60	Fluidised bed	MBM	
PDM Group Widnes	PDM Group Ltd	2.10	Fluidised bed	MBM	
Goosey Lodge Power Plant	Wykes Engineering Co.	5.00	Fluidised bed	Animal waste	
Slough	Slough Utility Services Ltd	35.00	Fluidised bed	Packaging/wood waste	
Arbre	Arbre Energy Ltd	10.62	Gasification	Energy crops	Not operating
Thornton Power Station	TPS (UK) LTD	9.00	Co-firing	Wood	
Weston Industrial Estate	Network Energy Ltd	0.50	Co-firing		
Peabody Trust, BEDZED	Peabody Trust	0.13	Reciprocating engine	Waste timber slurry & food	CHP, not yet fully operational
Holsworthy Biogas Company Project	Holsworthy Biogas Ltd	1.56	AD & reciprocating engines	Waste	
Scotland					
The Westfield Biomass Plant	EPR Scotland Ltd	12.5	Fluidised bed	Chicken litter	
Northern Ireland					
Blackwater	B9 biomass	0.2	Gasification/diesel engine	Forestry products	CHP
	Total biomass capacity	**159.7**	**MWe**		

Source: adapted from Ofgem list of acredited generating stations (RO and CCL), Ofgem website (http://www.ofgem.gov.uk/temp/ofgem/cache/cmsattach/9186_01_NOV_04_RO_data.xls), accessed 6/12/2004.

In recent years, the market for pellets has increased sharply, and reached almost 2 million tones in 2002 (Table 6). 115 pellet production plants have been identified in Europe in 2003, with capacity exceeding 3 million tones [8]. Sweden and Denmark are the biggest users, but the market is also growing quickly in Austria, Finland, Italy and Germany [8]. For all these countries, they have not confronted any problem with resources when dealing with CHP systems.

Besides biomass resources, technologies used in CHP is also prominent aspect to be considered. According to [4], which are established to promote cogeneration (CHP) systems application to the internal market, there are several cogeneration technologies that are used nowadays, which are; combined cycle gas turbine with heat recovery, steam backpressure turbine, steam condensing extraction turbine, gas turbine with heat recovery, internal combustion engine, microturbines, stirling engines, fuel cells, steam engines and organic rankine cycles (ORC). All these technologies are different in terms of capability and overall efficiency.

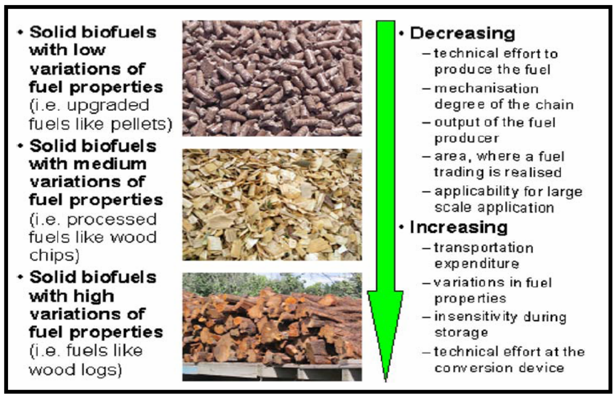

Figure 7: Market for solid biofuels [18]

Table 6: Pellet production capacities and use [8]

Country	Pellet production capacity (1000t/year)	Pellet use 2002 (1000t)
Austria	127.3	130
Denmark	673.5	400
Finland	335	25
France	131	Unknown
Germany	16 plants	37
Italy	44*	200
The Netherlands	1 plant	35
Spain	35	2
Sweden	927	900
UK	3 plants	Unknown
Estonia	220	Small
Latvia	75	Small
Lithuania	10	Small
Norway	53	1
Poland	151.6	Small
Russia	119	Small
Slovakia	14	1
European total	2915	1760
Canada		92
US		727

In the late 90's, ORC, stirling engines, and steam engine (screw type motor) were addressed as among that have potential to be developed [20]. Nowadays, the most recent technology in CHP system which is seen having the worldwide potential to be evolved is fuel cells. Thus, there are lots of R&Ds being carried out on this particular area.

Cited from [4], the overall efficiency and sustainability of cogeneration is specifically dependent on many factors, encompasses technology used, fuel types, load curves, the size of the unit, and also on the properties of the heat. Obernberger (1998) claimed via his study that "the basic requirements for the selection of an appropriate CHP process are a high electric efficiency to investment costs ratio and a well tested technology to ensure a continuous and undisturbed operation of the plant".

Bernotat and Sandber (2004) through their research have determined the potential of some countries in Europe which can implement the CHP system which are three Baltic States (Estonia, Latvia and Lithuania). This is due to rich biomass sources such as wood pellets which is available in these three countries. Installation of local CHP systems is actually can fulfill different needs; primarily they supply the area with heat and surplus power and has a backup function in the case of power grid failure [21].

CONCLUSIONS

In conclusion, it is not too much if to say that there is a bright future for biomass to be as the main contributor of energy supply as biomass itself possessing multi-applications namely bioelectricity, bioheating and biofuels. The main obstruction in realizing this goal is to firstly meet the Kyoto protocol target which is to increase the share renewable energy gross consumption up to 12% as well as to cut the CO_2 emission by 2010. In this context, it can only be accomplished if practical gaps to achieve Kyoto protocol of these three applications are identified.

Bioheating and bioelectricity are determined have a huge potential to be developed, however, due to the lack of current policies mainly in bioheating application as well as inefficient of bioelectricity itself, these two applications likely cannot to be further disseminated. Unlike biofuel and bioelectricity, there is no legislation has been performed by European Commission (EC) in matter to address and promote bioheating application in the market. This significantly contributes to a slow progression in bioheating, and simultaneously affects the EU's objective to fulfill Kyoto target since bioheating is actually a key market of biomass. On 6th July 2006, EC fortunately realize about this issue, and they are of now hardly working towards this legislation.

As far as this issue is concerned, cogeneration system so-called combined heat and power (CHP) is identified as among the way could be taken to treat this problem. This is parallel to the Directive 2004/8/EC, 2004 that addresses about the advantages using this system which can increase the overall energy performance and reduce CO_2 emissions. In the EU perspective, possessing abundant of solid biofuels make the CHP system is relevant to be run. In terms of technology, lately, there are lots of researches and developments have been carried out in this subject and the focus are more to improve the overall efficiency and capability of CHP systems. To this date, there are several types of CHP systems with different specification available in market such as microturbines, fuel cells, stirling engine, gas turbine with heat recovery, and etc.

Biomass resources and technologies being used are the most crucial aspects to be considered when dealing with CHP systems. These two factors give a big influence to the overall energy efficiency of CHP system. Standardization of the properties of solid biofuels suitable for CHP systems, for instance, is much welcomed (e.g. wood pellets). On top of that, the improvement of technology related to CHP system is the most prominent that must be taken into account. Introducing the Directives for promoting cogeneration applications (CHP) in the market (Directive 2004/8/EC), in 2004, is seen as among the wise ways taken by the EU.

Believing in biomass worldwide potential, thus, the EU specifically has implemented several ways inline to diversifying their energy supply and abating CO_2 emissions. Not only Europe, biomass, as is said, has enormous potentials to be exploited in other regions all over the world depending on their climate, land availability as well as national policies. The lack of demand on biomass energy is among factors that have as well contributed the slow progression of biomass energy penetrating the market. The only approach to encourage demand is via appropriate legislation tools implemented at national level. Besides that, research, technological development and demonstration are such a ways that also can be done in promoting biomass used. Nevertheless in way of exploiting all the biomass resources, there are some aspects that we must consider and the most prominent one is environmental concerns. This just for ensure our ecosystem has not been threaten by strong determination of us in seeking these all valuable energies.

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