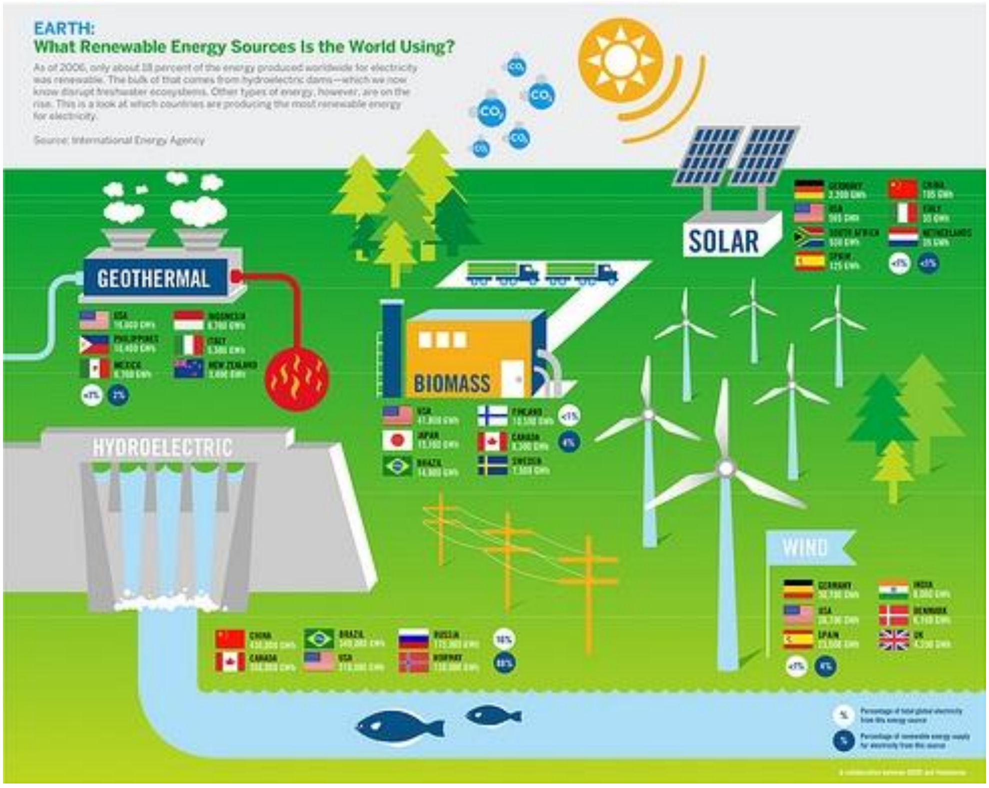
Comparison of woody pellets, straw pellets, and delayed harvest system herbaceous biomass (switchgrass and miscanthus): analysis of current combustion techniques determining the value of biomass



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Abstract

Since the energy consumption is growing fast, it is important to find alternative resources for the future generation energy supply. This study is going to compare the woody pellets, straw pellets and delayed harvest system biomass (switchgrass and miscanthus) from the combustion technique perspective. What problems during the thermal conversion will determine the value of herbaceous pellets lower than wood pellets? Both literature review and consulting with experts are used in the research. Although at this moment, application of herbaceous biomass will cause problems like corrosion, slagging and fouling, many solutions have already in their experimental stage. As the need of energy increase, the market for herbaceous biomass is bright.

Key Word: herbaceous biomass; combustion technique

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Introduction

Background

The world energy consumption is getting intense year by year. In the IEO 2010 projections, it is remarkable that total world consumption of marketed energy increases by 49 percent from 2007. (EIA,2011). Under the big pressure of increasing energy demand, every country will not only face the challenge of energy supplies but the market also stimulates the research on finding the alternative energy resource. In recent years, many researches have been done on biofuels.

Many researches are contributed to find an alternative energy resource for the future. It is believed that the new energy resource is also sustainable for environment. The whole world is putting environmental issues on urgent agenda. European countries especially take the initiatives by applying policy tools like EU-ETS, or CDM and increasing the share of renewable energy. Biomass is not a new topic. Biomass takes one third of the world's energy consumption, where includes 11.5 million tonnes of wood pellets (develop sustainable trade). It is one of the largest internationally traded solid biomass today (Sikkema et al., 2011).What makes the wood pellets market so attractive to people? Wood pellets have a better storability and relatively easier handling than wood chips or agricultural residues. It also has a low moisture content, relatively high energy density (approximately 17.5 GJLHV/ton), and possibility for a long transport (economically more feasible above 9300km than wood chips) (Sikkema et al., 2011). Another advantage of wood pellets is that it is clean and CO_2- neutral compared with coal and petroleum, so it is rather convenient for the users for not dealing with the end-pipe products. However, besides all these advantages as an energy source, the sustainability has gradually been taken into account. The wood resource is not inexhaustible. Countries with less forest have more pressure for wood pellet market as they rely on import from other countries. Compared with agricultural residues, the raw material competition will become a problem in the future market. As consequence, all the wood related industries will be affected by the increased wood price. What is worse, this situation may even lead to an ILUC (the impact of indirect land use change) effect, because the supply cannot meet the huge demand in the future, people will start to cut down the forest.

Thus, finding the alternative resources for long term is urgent. The herbaceous pellets have emerged as a choice. Compared with wood, these materials are much easier to get with less potential for ILUC effect. Especially for those countries with less wood resource, herbaceous pellets provide a broader market. However, because of the infancy of the market, the logistic and economic values still needs to be determined, which is also constrain for the market development, because the stakeholders has to be convinced by the value (Wach and Bastian,2008). The problems for herbaceous pellets are that countries do not have standards on the trade, techniques and the required chemical content in the raw material etc. Feasibilities of MBP (mixed biomass pellets market in European countries has been investigated though a European project (pellet @ las). In this project, they investigate the herbaceous pellets market in different European countries and summarize the barriers and current market situation. What makes the value of herbaceous pellets differ from wood pellets? At this moment, we know that pretreatment, extra equipment needed for emissions and ash content, adaptation for the boilers are all negative factors for the reason why the price of this kind of pellets is lower. But, how factors influence the value still needs more study. Therefore, more researches are undertaking to get the visible pictures for the whole chain.

Objective and research questions

As there are many factors determine the value of pellets, such as emission standards, technique barriers, transportation system, storage, and improve the raw material etc. also play important role in influence the value. However, in this report, only the current combustion technique barriers will be discussed due to the limited time.

The objective of this study is going to illustrate the factor of combustion technique barriers which is determining the value of these so called ‘dirty pellet’. The three categories of pellets will be compared: wood pellet, straw pellet, and delayed harvest system biomass (miscanthus, and switchgrass) It is important to understand what criteria determine the quality of these pellets, e.g. the harvest season, high ash content, and new techniques.

In order to get the research objective, research questions are formulated:

What will determine the value of herbaceous pellets in comparison of wood pellets based on the factor combustion techniques?

a. what is the definition of wood pellets, straw pellets and delayed harvest biomass?

b. what are the problems in thermal conversion determining the value of mixed biomass pellets in comparison of wood pellets?

These two activities will be undertaken during the research:

1. Defining pellets: Wood, Straw and mixed (switchgrass and micanthus, delayed harvest). Choose standard for wood and straw pellet that could be used for this project. Database with contents of switchgrass and miscanthus will be set to give a visual picture so that it is easier to compare with wood pellets which is already have standards.

2. Review current combustion techniques that determine value of non-wood vs wood pellets

Methodology of this study

Literature review will be based on the reports from the European project (pellet @ las) and other scientific paper. Data collecting will start from the research institute database such as ECN-Phyllis, USA- DOE database, and investigation of pellet project Biomatch. During the research, personal information from consultant with experts will also be used in the report.

Methodology for research question 1

To give the definition of different pellets:

Although there are many standards in European countries, the standards of wood pellets will be selected from the European Committee for Standardization (CEN). The CEN under committee TC335 has published a number of standards and pre-standards for solid biofuels. These standards have been well accepted at this moment.

The database for straw and delayed harvest system biomass (miscanthus and switchgrass) will be selected from the report from pellets @ las, ECN database phillys, and other literatures. It might be that in this project or database, they also choose the CEN standards. It will be determined in further research process.

Methodology for research question 2

Analyze the factor: current technique barriers

The technique barriers will be analyzed with the knowledge from meeting with experts, and literature review. The meeting includes ECN interview and expert Jaap Koppejan.

Definition of pellets

The standards for pellets are gradually completing. Because the wood pellet has booming in Europe, the standards are quite clear. However, the herbaceous pellet market is at its infancy stage, the product is not put into commodity. Thus, to have a general database is necessary for further research.

CEN is not the only pellets standard. There are also national standards like German DINplus and Austrian ÖNORM M 7135. In the European pellets conference in 2010, it was pointed out that *Now these technical specifications are upgraded to full European standards (EN). When EN-standards are in force the national standards has to be withdrawn or adapted to these EN-standards* (Alakangas, E.,2010).

In this following paragraph, standards for wood pellets, and discussion on the database for herbaceous biomass will be given. Since the nation standards have to compliance to the EN standards, and also the wood pellets standards are well accepted in the market, the wood pellet standards are chosen from CEN standards.

Wood pellet

Wood pellets are defined by CEN TS 14961 as “woody biomass”. In the report of pellets @ las, it is described *Sawdust would then be classified as “wood processing industry, by-products and residues”, usually chemically untreated, with or without bark.* Wood pellet is less problematic for emission regulations and combustion equipment (Voulgaraki et al,.2006). Therefore, the market is quite active. Due to the advantages compared with ‘dirty pellets’, the woody pellets are also more acceptable by the end users. This is also due to the low ash content. Table 1.1 gives a clear guideline for wood pellets.

Table 1.1. overview of different woody biomass fractions with regard to their use in pelletisation

parameter	unit	Limiting/ Guideline value	Average value of the raw material	comments
Net calorific value	kWh/kg	h	Approx. 4.9 Approx. 5.2	Hardwood(beech) Softwood(spruce)
Ash content	wt.% (d.b)	0.7	1.0 -1.3 0.37-0.77	Hardwood(beech, oak) Softwood(spruce, fir)
Nitrogen content	wt.% (d.b)	0.3[1)]	0.21-0.41 0.07-0.11	Hardwood(beech, oak) Softwood(spruce, fir)
Sulphur content	wt.% (d.b)	0.03[1)]	0.02-0.05 0.01-0.05	Hardwood(beech, oak) Softwood(spruce, fir)
Chlorine content	wt.% (d.b)	0.02 [1)]	Approx. 0.01	Hard and soft wood
Mineral Contamination	wt.% (d.b)	l	Possible	IWC from BPS, depending on c area, FWC caused by harvest a IWC from WWI
			Low Very low	Sawdust and wood shavings

From pellet handbook; Stockinger and Obernberger, 1998; BIOBIB,2003; Stockinger and Obernberger, 1998; Phyllis,2000.

Explanations: [1)]… limiting value according to prEN14961-2 for pellet class A1;

[2)]…spectrum of the foremost particle size according to ÖNORM 7133, extreme values being possible both beneath and above; h …as high as possible;

l … as low as possible;

Both the ash content and chemical compound are quite low in wood pellet in the above table. Such a restrict limiting is very difficult for herbaceous pellet to reach.

Herbaceous biomass

The quality of herbaceous biomass is driven by many factors. The soil type, fertilizer, and climate can all make different result of the chemical content. The table 1.2 switchgrass sample analysis and table 1.3 miscanthus sample analysis below is from the Phyllis, the database of biomass and waste. They have the data on different biomass type.

The two types of crop have many advantages being as energy crop. For they are high yielding compared with wood, low cost of production and high nutrient use efficiency (Stamler and Samson, 2008; renewable energy crop, 2010)

Table 1.3 switchgrass sample elemental analysis

	Ash content (wt.%)	C (wt.%)	H (wt.%)	O (wt.%)	N (wt.%)	S (wt.%)	Cl (wt.%)	K (mg/kg)	Na (mg/kg)	Mg (mg/kg)	Ca (mg/kg)
Dakota switch grass	3.6	47.4	5.75	42.3	0.74	0.08	0.034	ND	ND	ND	ND
Summer switchgrass	2.7	47.5	5.8	43.6	0.36	0.05	ND	ND	ND	ND	ND
switchgrass	10.1	47.8	5.76	35.1	1.17	0.1	ND	ND	ND	ND	ND
switchgrass, early cut	5.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
switchgrass, first harvest	5.8	ND	ND	ND	0.27	ND	ND	ND	ND	ND	ND
switchgrass, first harvest after storage	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
switchgrass, late cut	4.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
switchgrass, second harvest	4.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
switchgrass, second harvest after storage	5.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Database from Phyllis

ND Not Determined

K, Na, Mg, Ca are measured from sample (dry)

Table 1.4 miscanthus sample elemental analysis

	Ash content (wt.%)	C (wt.%)	H (wt.%)	O (wt.%)	N (wt.%)	S (wt.%)	Cl (wt.%)	K (mg/kg)	Na (mg/kg)	Mg (mg/kg)	Ca (mg/kg)
miscanthus	4.8	47.9	5.5	41	0.54	0.11	0.18	ND	ND	ND	ND
miscanthus giganteus	1.5	48.4	6.3	43.3	0.3	0.1	0.13	4100	290	ND	ND
miscanthus grass	9.3	39.8	5.07	44.2	1.07	0.05	0.56	ND	ND	ND	ND
miscanthussinensis gracillimus, Oregon	3.4	47.7	5.75	42.7	0.45	0.05	0.18	ND	ND	ND	ND
miscanthus straw	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
miscanthus, fresh	4.8	47	5.69	42.1	0.54	0.08	0.468	12000	260	540	2400
miscanthus, high K	1.5	48.1	5.8	41.9	0.3	0.1	0.16	ND	ND	ND	ND
miscanthus, low K	1.1	49	6	43.8	0.6	0.1	0.1	ND	ND	ND	ND
miscanthus, silage	5	47.1	5.78	41.8	0.45	0.08	0.063	12000	210	530	2000
miscanthus, silage, dried	4.7	47.3	5.79	41.9	0.43	0.06	0.474	890	160	390	1600
miscanthus, silberfeder, Oregon	3	47.3	5.75	43.5	0.33	0.06	0.06	ND	ND	ND	ND
miscanthus, sorghastrum avenaceum, Oregon	4.2	47.3	6.01	42.1	0.32	0.04	0.04	ND	ND	ND	ND

Database from Phyllis

ND Not Determined

K, Na, Mg, Ca are measured from sample (dry)

The database Phyllis from ECN gives the ash content and other chemical content. The data is mainly about the thermal conversion of biomass into energy (Rabou et al., 2004).From the table1.2 and 1.3, the ash content miscanthus and switchgrass are very high compare with wood. The ash content from standards of wood pellets is 0.7 wt. % (d.b), while the lowest ash content of switchgrass is 2.7 wt.% (d.b) and for miscanthus is 1.5 wt.% (d.b). It is quite notable that miscanthus giganteus has very high quality compare to others, which the Nitrogen content and Sulfur content are also low.

However, one pitfall of this database is that it does not provide the soil type and climate information. These two factors have a vital influence on growing condition of the plant. Therefore, the Phyllis database is just to give general information. The table below shows the difference between two soil types: sandy loam soils and clay loam soils. The soil type can influence the ash content quite strongly. Therefore, if Phyllis also separates the soil type, the database is more accurate.

Table1.4 Energy and ash content (%) of fall and spring harvested switchgrass

component	sandy loam soils		clay loam soils	
	spring 1998	fall 1998	spring 1998	fall 1998
	switchgrass ash contents(%)			
leaves	6.2	7.4	7.67	9.19
leaf sheaths	2.46	4.47	3.67	5.57
stems	1.08	2.39	0.98	2.4
seed heads	2.38	4.66	n/a	5.24
weighted average:	2.75	4.5	3.21	5.24
	switchgrass energy contents(%)			
leaves	18.44	18.67	18.38	17.56
leaf sheaths	19.19	18.22	18.27	17.87
stems	19.41	19.09	19.69	18.69
seed heads	19.49	18.56	n/a	18.51
weighted average:	19.11	18.78	19.07	18.23

n/a notavailable

Samson et al,. 2005; Samson et al,. 1999

In Table 1.4, both the soil type and delayed harvest system can improve the quality of the herbaceous biomass. Although the energy contents did not change too much, the ash contents were quite different from sandy and clay soil as well as the season to harvest.

The quality of herbaceous biomass can be improved by several ways, such as leached straw and delayed harvest of the switchgrass. Currently, some chemical compound in herbaceous pellets will cause problems for the combustion equipment. That is also one reason why this type of pellets is not welcomed by markets. In the research of Jenkins et al. (1999), *leached rice straw is technically suitable as fuel in existing biomass boilers of various types under normal operating conditions and temperatures.* Here are some figures on straw and leached straw, as well as delayed harvest switchgrass.

Table 1.5 biomass fuel data on straw, switchgrass, and miscanthus biomass

	unit	Straw[1]		Switchgrass[2]	
		Yellow straw	Grey straw	Switchgrass[3]	Overwintered Spring harvest[3]
water content	%	10 ~20	10~20		
volatile components	%	>70	>70	n/a	n/a
ash	%	4	3	4.5-5.2	2.7-3.2
potassium	%	1.18	0.22	0.38~0.95	0.06
carbon	%	42	43	n/a	n/a
hydrogen	%	5	5.2	n/a	n/a
oxygen	%	37	38	n/a	n/a
chloride	%	0.75	0.02	n/a	n/a
nitrogen	%	0.35	0.3	0.46	0.33
sulphur	%	0.16	0.05	n/a	n/a
calorific value, water/Ash-free	MJ/KG	18.2	19.4	19.4	n/a
calorific value, actual	MJ/KG	14.4	10.4	18.2~18.8	19.1
ash softening temperature	˚C	800-1000	950-1100	n/a	n/a

[1]Biomass consulting & solution development INTL

http://www.nrg-consultants.com/chppowerplantscogeneration/wholestrawbalegasifiers/strawasafuel/index.html

[2]Samson et al., 1999; Goel et al., 2000;Samson et al., 2005

http://www.reap-canada.com/online_library/feedstock_biomass/REAP-Canada-S.%20BaileyStamler-March%202008.pdf

[3] 8 year old cave in rock switchgrass field near Arnprior

Both leaching and delayed harvest system are quite useful ways for solving the unpleasant quality problems of herbaceous biomass. Lying straw in the field and expose to the rain can reduce potassium and chlorine which will cause corrosion to the combustion equipment. After the process of leaching, the color of the straw turns from yellow to grey. In the experiment of leaching straw (data is in table 1.6), *leaching experiment on barley straw has been carried out. The result showed that after 150 mm rain, the chloride content had dropped from 0.49% to below 0.05% and for potassium from 1.18% to 0.22%.* As in table x.x, the content of K, Cl, and S are reduce significantly. For delayed harvest system, Elbersen,(2005) pointed out the advantages of delayed harvest system for crop are: it has lower transport cost and does not need drying which benefit the storability. The system also has a good stand management.

Improving the quality of biomass by control the growing condition can make the herbaceous pellets more competitive. Although currently, it is difficult to reach the quality standards as woody pellets, the low cost and high productive are still attractive for the future market to consider this new resources.

Below the table 1.6 shows the comparison of wood pellet and herbaceous biomass from the access to the raw material, the growing factors of the crop, equipment and techniques, as well as regulation limits

Table 1.6 a brief comparison of woody pellets, straw pellets, and delayed harvest system biomass (Miscanthus and switchgrass)

	Biomass type		
Barriers and obstacles	Wood pellet	Straw biomass	Miscanthus and switchgrass biomass
Definition of the pellet	**A≤0.7,S≤0.05,N≤0.3,C≤l0.03**[4]	**A≤5, N≤0.5-0.8,S≤0.1-0.3, Cl≤0.2-0.4**[5]	**General for all herbaceous Biomass: A6.0 or A6.0+, N0.5 or N1.0, S0.10 or S0.10+, Cl0.10+** [2]
Raw material	Expensive, price rises as material become competitive with other wood related industry in the future	Easy to get	Easy to get
Factors for the quality of Raw material	Wood type	Soil, climate, fertilizer, Harvest seasons	Soil, climate, fertilizer, Harvest seasons
equipment	mature	Adaptation for ash content needed, gas filter	Adaptation for ash content needed, gas filter
technique	mature	Boiler technology needs updated	Boiler technology needs updated
Legal framework	**a.** General classified by CEN TS 14961. National standards are being developed by each county. The comprehensive framework is still under developing. **b.** For small scale applications Austrian ÖNORM M 7135 and The German DINplus are Wildly used. [2]	**a.**CEN standards: prEN 14961 Fuel specifications and classes, multipart standard: Part 6 Non-woody pellets for non-industrial use; fuel quality assurance, multipart standard: Part 6 Non-woody pellets for non-industrial use [1] **b.** Not applied for small scale use.	**a.**No national quality standards so far, but can be derived from "herbaceous biomass" [2], some EU countries are already taking initiatives for developing the standards[1]. **b.** Not applied for small scale use.

1. Obernberger and Thek,2010
2. Voulgaraki et al., 2008
3. CEN TS 14961
4. CEN/TS 335-WG2N94

From the comparison, it is clear that herbaceous biomass is high in ash content, nitrogen content, chlorine content. In this case, the ash empting time is higher than using wood pellets. Nitrogen content higher than 0.6% will contribute to enhanced production of NOx. High chlorine content will cause corrosion for the equipment.

Besides the CEN preEN14961, according to the report from pellets@las, *since 2007.11.01. there exists the Austrian standards ÖNORM C 4000: compressed miscanthus-Requirements and test methods (National supplement referring to Prestandard CEN/TS 14961), in which miscanthus is classified as A4.0/A0.6(ash content ≤6%), N0.5(nitrogen≤0.5%),Cl0.07(chlorine≤0.07%) and S0.05(sulphur≤0.05)* Voulgaraki et al., 2008). There is also a France national standard called “NF Granules Biocombustibles” FCBA. It defines both the large scale and domestic scale application.

Because the market for herbaceous pellets is still in its infancy stage, there are not many standards or standards are still being pending. Together with the unfavorable chemical compound, the problems put a great pressure for making this type pellets into commodity. Furthermore, the emission regulations also constrain the herbaceous pellets for small scale use. For compare with large scale application, the emission standards are stricter. For these reasons, it is hoped that techniques for burning ‘dirty pellets’ can compensate the low quality in order to reach the regulations. This is also a driver for adaptation of techniques.

Technique barriers influence the value of pellets

The boiler technologies are necessary to update for lower quality pellets due to the high ash content and other chemical compound in comparison with wood. More importantly, the national environmental laws should be less strict in order to make the low quality pellets survive during the development. Figure 2.1 presents environmental standards and market incentive stimulates the development of technique. The adaptation of combustion technology is necessary to meet the environmental standards. In this way, the new type of pellets can be put into market. Otherwise, they can only be treated within small scale. Because of the low cost of biomass, if the equipment can burn herbaceous pellets and does not cause problems, the economic effectiveness will be better than using the woody pellets which may run into trouble in the future because of the ILUC (indirect landuse change) effects.

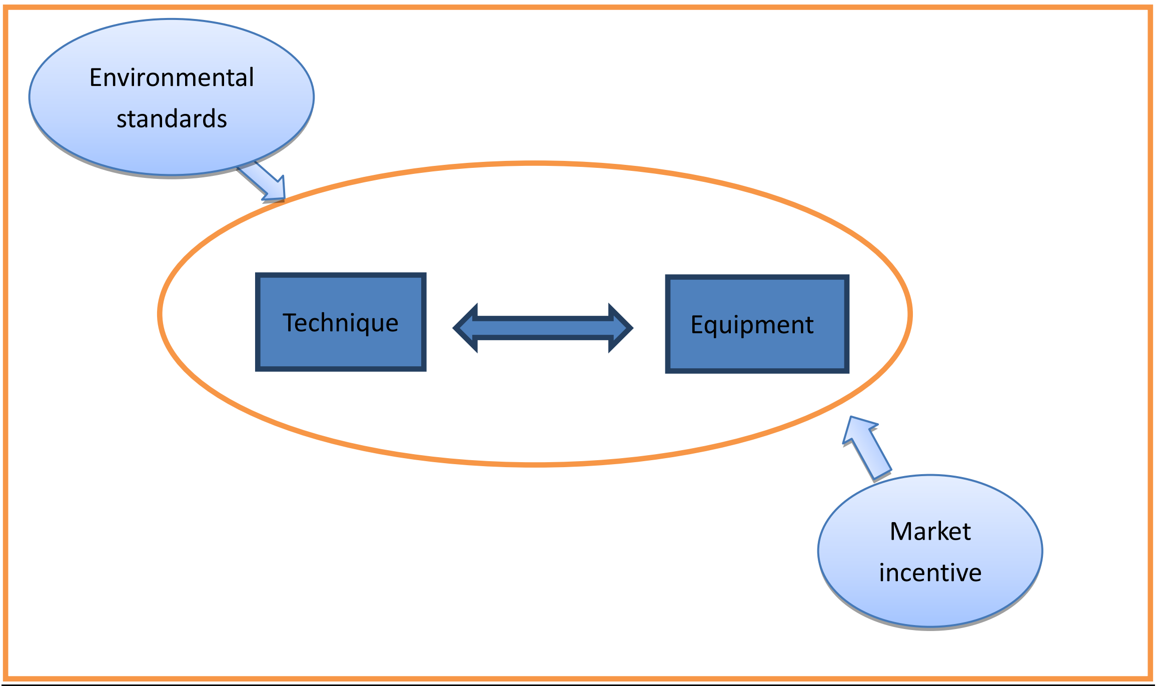

Figure 2.1 the factors affect the development of technique and equipment

Thus, improving the technique to reach the standard is important for herbaceous pellet chain. Strong interactions are between each factor and the value of the pellets, but for each factor, sometimes they are affecting each other also. The technique and equipment development should be seen as one system. For the research and development will adapt the equipment, the insufficient performance of equipment will stimulate the research on technique. The emission standards restrict the use of herbaceous pellets because of the unfavorable chemical compound, it stimulate the boiler technology developing as well. The market is always searching for new options. The utilization of non-wood pellets is an alternative for the future, for it would set up a competition between the wood related industries. Furthermore, wood is a precious resource not only used as all kinds of living material for people, but it also comes from the forest which is the edge of danger in many places for cutting down the trees. Therefore, if the boiler technology can be adapted in the future, and provide a relatively reasonable price of adaptation, the herbaceous pellets will have a bright future. Energy efficiency is related to ash problems in this case, as slagging problem may reduce the energy efficiency. In all energy researches, the efficiency is an important issue. If the efficiency is high, it will benefit on many aspects, e.g. reduce the biomass input, and probably the price of energy will go down since herbaceous crops can be acquired at a low price. In many investigations, the high ash content seems to be a threshold for development of herbaceous pellets as well as alkali metals (Obernberger, 2006: Voulgaraki et al., 2009).

In the next section, the review of current combustion technology and the technique barriers both for woody and herbaceous biomass will be given.

Current Technique barriers

The current combustion technologies are classified into three groups: residential heating, industrial heating and co-firing. In the section of regulation, the problem of residential heating scale is mainly on the emission standards limits It is also not cost effective to put emission filter on small scale use. For industrial heating, the biggest barrier is ash behavior and alkali chemical problems. Because of the unfavorable chemical compounds, the equipment will have the risk on corrosion, slagging and fouling. These problems will be described in the following passage. According to experts opinion, the power companies have already taken the initiatives to adapt the coal plant, as the price of CO_2 emission will go up though ETS (emission trading scheme) in the future. It is will quite expensive to burn coal. Table 2.1 makes a brief summary on the issues. The table also shows the power plant trends, concerns and part of the solutions for the concerns.

Table2.1 the overview of current combustion technology

	Residential heating	Industrial heating		Co-firing
		Fixed bed combustion	BFB/CFB	
description	Domestic heating	up to ± 20 MWth	only for plants larger ± 20 MWth, ±30MWth	direct co-combustion in coal fired power plants/ indirect co-combustion with pre-gasification or other thermal pretreatment
Trends	1.advances in design; 2.use of pellets; 3.low emissions	1.standardized packages for industrial sizes; 2.fuel flexibility; 3.combined heat& power at smaller scale	1.increasing unit size; 2.higher efficiencies; 3.fuel flexibility	1.high efficiency; low investment costs; 2.High CO2 avoidance per tonne of biomass; 3. new PC units up to 40% of co-firing
Concern	particle emission	1.fuels with low ash melting 2.temperature; ash slagging	Using pellets possible but too expensive [1]	Coal price integrated with CO_2 may increase to 150/ton in the future[a]
solution	small scale dust removal systems decrease the moisture content of biomass [b]	spraying ammonia sulphate can reduce corrosion and fouling	The development of new plant is towards BFB or CFB	Power companies will use coal as basis and make the plant feasible for other biomass also.

Based on van Loo and Koppejan, 2007.

[a] personal contact with expert Jaap Koppejan

[b] Foppa Pedretti et al., (2010)

Even wood pellets have relatively mature market and logistic, there are still many issues need analysis, not mention a new infant market of herbaceous pellets market.

Current problems for Wood pellets

According to Junginger et al. (2009), they held a workshop in the Netherlands, in this workshop, more than 40 pellet traders, large scale users and scientists were coming, where the members of IEA Bioenergy Task 40 on sustainable international bioenergy trade also joined. In this workshop, a questionnaire about the main barriers of wood pellets trade in next 5 years was given to participants. The logistical barriers for pellets transports and meeting technical quality standards are not chosen among all the participants, while the competition for feedstock and policies large-scale use (co-firing) was picked up as two important barriers. The rest barriers are: competition with natural gas, coal… sustainability criteria; policies for small-scale use (residence. Heating); high investments for pellet stoves; lack prices & traded volumes statistics.

This information are very helpful for the market of herbaceous pellets, since there will be some similarities between the development process of wood pellets and herbaceous pellets.

Current problems for herbaceous pellets

The boiler and large scale firing plant technologies are currently matched for the combustion of wood and wood pellets. In Voulgaraki et al.,(2009), it is said that ‘ pellets boilers for the residential heating sector are optimized for the use of wood pellets only.’ The project pellets @ las has done many feasibility study on mixed biomass pellets (pellets @ las, 2009). In their conclusion, it is possible to use mixed biomass pellets in large scale plants without causing serious problems if the gas cleaning and relative equipment is used. The problems are more for the small scale use, because the boilers needs to be adapted and national environmental laws need to be consider the emission threshold for herbaceous and mixed biomass pellets.
It is feasible to achieve the standards and bring down the rate of the problems for low quality pellets during combustion. The only concern is whether it will be high investment on the extra equipment or changing the operation parameters. The Denmark has already years of experience for combustion of straw. The government also give subsides for promote research on combustion technology of boiler. In 2004, Kristensen et al. have done a research on small-scale batch-fired straw boilers, and their result is quite optimistic:’ the typical efficiency has been increased from about 75% in 1995 to about 87% in 2002. Similarly, the carbon monoxide emissions have been reduced from 5000 PPM (reference value 10% O_2) in 1995 to less than 1000 PPM in 2002.’ They also explained how to get these improvements: ‘a better insulation inside the combustion chamber, more efficient techniques for supplying air to the combustion process, improved cooling of the flue gas, and optimization of the electronic control unit for the air supply.’

By mixing different biomass may improve the quality and reduce the ash content. However for a mixed biomass pellets, it will have more difficulties than only use a single category herbaceous pellets. Especially, it is too difficult to determine the chemical compound like Ca, Mg, and Cl which will decrease the ash melting point. If the mixed content of chemical compound is not correct, it will increase deposit formation and slagging (Obernberger et al., 2006). However, the chemicals in herbaceous plant depend on many factors, such soil type, fertilizer, and weather data. Thus, in order to know the percentage of composition of chemicals result in an ash melting point and at what level the energy efficiency will decrease sharply, more researches are needed. It is notable that some heating system manufacturers in Austria already offer special boilers for agropellets. This initiative may break the technique bottleneck in Europe low quality pellets market (Voulgaraki et al., 2009). Table explains the combustion problems detailed by chemical compound. The ash melting behavior is so complicated that each chemical compound may have interaction with the other. In this case, some ratios are import for operation.Table 2.2 describe the thermal conversion problems by list different chemical compound

Table2.2 Quality characteristics of biomass solid fuels, their relevance and critical limits or orientation values

quality characteristics	Effect	critical limit	reducible by technology
water concentration	more emissions, decreasing heating value and efficiency, higher proportion of ballast content, decreasing storability	wood:<300 gkg^{-1} FM Gramineae: <230 gkg^{-1} FM	- -
N concentration	NOx emissions in unstaged combustion	10 gkg^{-1}DM	Staged combustion[1]; Steam gas recirculation[1]; Air staging[2]
S concentration	SO_2 emissions, higher flue gas dew point	<3gkg^{-1} DM	Fluidized bed combustion chambers
Cl concentration	Corrosion by forming KCl, HCl emi	2gkg^{-1} DM	Wet torrefaction:98% of Cl will be removed[3]
	Dioxin emissions		carbon filter[3]
K concentration	Corrosion by forming KCl, lowering of the ash melting point	dq	-
Na concentration	Lowering of the ash melting point	dq	-
Ca concentration	Increasing the ash melting point; slagging	dq	-
Mg concentration	Increasing the ash melting point	dq	-
ash amount	Lowering of the efficiency by Slagging; higher operating costs due to remove the ash periodically.	dq	Ash compaction system (the empty ash period is Longer); Fully automatic de-ashing Systems (with an extra container, empty time: about once a year) [2]
		Orientation value	
Ash melting temperature	Lowering of the efficiency, higher operating costs	>1150 ˚C	-
heating value	improved efficiency, decreasing emissions	>14000kJ kg^{-1} raw substance	-
volatiles	Improved ignition and combustion coarse, increase of the emissions in domestic combustion units	Depending on combustion technology	Desirable for large scale Combustion or gasification because easier for regulating the process
heavy metals	Increase in heavy metal emissions	As low as possible >150 kgm^{-3}	Most heavy metals except Hg and Cd, can be found in

		The ashes[1]
density	higher transport and storage volume	Pelleting technique

- ,not possible; +, if possible; - -, difficult to realize; dq, difficult to quantify
Based on: [1]. Lewandowski and Kicherer, 1997
[2].Obernberger I., 2006
[3.] Personal contact with experts from ECN

In Monti et al., (2008)'s experiment, they tested the mineral composition and had a result that *high Si/K or Ca/K ratios are known to reduce slagging; Ash content was found to be strictly related to C and Ca, and secondary to Na, Si and Cl; N was positively related to K and P, and negatively related to Si, Si/K and Ca/K ratios; Cl was negatively related to Si, Si/K and Ca/K; Moreover, K was highly related to P, and to a lesser extent to Mg, while P was negatively associated with Si/K and Ca/K ratios.* While in the other research, the S/Cl ratio in the feedstock affects Cl deposition and corrosion. If S/Cl ≤ 2, the equipment has a high risk of super heater corrosion; but if S/Cl ≥ 4, there is non-corrosive[1]. Van Loo and Kappejan (2007) pointed out that spraying ammonia sulphate can reduce corrosion and fouling. For the Cl, the wet torrefaction can remove 98%. The salt will get into the solution and easy to wash away. However, all these solutions are at experimental stage, therefore, it is difficult to have an economic analysis at this moment.

[1] Personal contact with expert Jaap Koppejan

Conclusion

The rapid energy consumption stimulates the energy market searching for more alternative resource. Wood pellets market has made a great progress in world solid biomass market. However, the long growing period and competition with paper related industry may result in the shortage of biomass. Therefore, the herbaceous pellets show up as a good choice because it is abundant and also CO_2 neutral. In this study, three types of biomass are compared: wood pellets, straw pellets, and delayed harvest system biomass (reed, switchgrass and miscanthus). Woody pellets are defined by the CEN TS 14961, while the rest herbaceous pellets are not put into clear standards or still pending. However, there are already some research institute take the initiatives to define these herbaceous pellets. Also the national standards like Austrian ÖNORM C 4000 and France NF Granules Biocombustibles exists. This will serve a good basis for the CEN prEN 14961 part 6.

For the clear standards of 'dirty pellets' are still not come up, the technique may compensate the quality limits of herbaceous pellets. Due to the alkali chemical compound and high nutrients in the plant, the slagging, corrosion and fouling problems become the major barriers for burning these type of biomass. Some countries have already started the boiler experiments to test the unproblematic operation for herbaceous biomass. At this moment, it is not cost effective for small scale use because the high investment on emission filters, but for big scale use, herbaceous pellets have a bright future due the high integrated CO_2 price. There are also some chemical compound ratio can give indicators for operation.

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Appendix

Table 1 specification for French, “agropellet” quality standards

specifications	AGRO+	AGRO
dimensions	D=6to8mm±1mm L=10 to 30 mm	D=6 to16mm±1mm L=10 to 30 mm
moisture content	⩽11%	⩽15%
net caloric value(MJ/KG)	⩾15.5	⩾14.7
net caloric value(KWh/KG)	⩾4.3	⩾4.1
bulk density(Kg/m3)	⩾650	⩾650
Mechanical durability	⩾95%	⩾92%
amount of fines(after production)	⩽2%	⩽3%
ash content	⩽5%	⩽7%
Cl content(on dry matter)	⩽0.2%	⩽0.3%
N content(on dry matter)	⩽1.5%	⩽2%
S content(on dry matter)	⩽0.2%	⩽0.2%
Ash temperature	Agro ⩾800◦C	Agro+ ⩾1001◦C
Heavy metals(mg/kg)		
As	≤1	
Cu	≤40	
Cr	≤10	
Cd	≤0.5	
Hg	≤0.1	
Ni	≤15	
Pb	≤10	
Zn	≤60	

Source: Voulgaraki et al,. 2008