Co-utilisation of Biomass with Fossil Fuels

Summary and Conclusions from the IEA Bioenergy ExCo55 Workshop

Co-utilisation of biomass with fossil fuels can be an attractive solution to increase the proportion of renewable energy. Co-utilisation in modern, efficient plant has the potential to utilise large quantities of biomass and should be considered alongside other bioenergy technologies. To date co-firing biomass with coal has been the most attractive scenario for co-utilisation, but recent increases in the cost of oil have focussed attention on blending liquid biofuel with diesel and petrol. Policy instruments supporting co-firing must be carefully designed from technical, commercial, and environmental viewpoints.

IEA Bioenergy: ExCo: 2006:02

INTRODUCTION

This publication provides the summary and conclusions from the workshop 'Co-utilisation of Biomass with Fossil Fuels' held in conjunction with the 55th meeting of the Executive Committee of IEA Bioenergy in Copenhagen on 25 May 2005. The purpose of the workshop was to inform the Committee about the development of biomass co-utilisation with fossil fuels - in particular co-firing - and about the remaining technical or other barriers that need to be overcome in order to accelerate the expansion of co-utilisation technologies in the market.

Biomass is the only renewable energy source that can replace fossil fuels directly, either completely in small-scale applications or by blending solid, liquid, or gaseous biomass fuels with corresponding fossil fuels in large-scale applications. Thus co-utilisation of biomass fuels with fossil fuels is a quick and relatively reliable way to reduce greenhouse gas emissions and preserve natural resources. It is therefore a sustainable, interim mechanism for meeting commitments to the Kyoto Protocol.

BACKGROUND

Concerns about the present global energy situation and the impacts of climate change have given new impetus to deployment of renewable energy sources to replace fossil fuels. National governments and international organisations are developing policies to address these issues according to the particular needs of the country or larger economic and political grouping, e.g., the European Union.

Bioenergy is recognised as the most important and potent renewable energy source. At present it contributes 3.3% of OECD energy demand (Figure 1). Bioenergy is unique among the renewable energy sources in that it can directly replace fossil fuels: solid biofuel can replace coal, liquid biofuels can supplement petrol and diesel, and biogas as well as synthetic natural gas from biomass can be fed into natural gas pipelines after purification and upgrading. In many cases there can be either partial or complete substitution, resulting in pure or blended fuels.

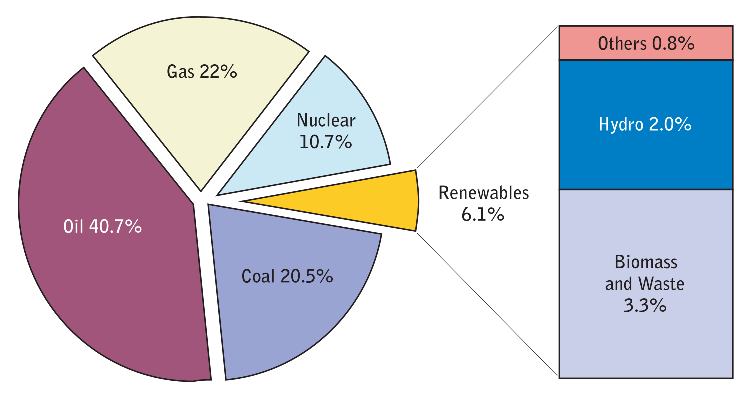


Figure 1: *2003 Fuel Shares of Total OECD Primary Energy Supply [1]*

Co-utilisation is the term commonly used to describe the simultaneous use of various fuels in the same energy conversion plant. As far as bioenergy is concerned it applies to solid (e.g., biomass/coal), liquid (e.g., ethanol/petrol) and gaseous (e.g., biogas/natural gas) fuels. It is also possible to co-utilise fuels of different phases such as liquid and gaseous biofuels in combination with solid fuels (e.g., bio-oil/coal, fuel gas/coal). In the first example the biofuel is blended with the fossil fuel and then fed simultaneously into the combustion zone while in the second example the biofuel is fed into the combustion zone separately from the fossil fuel.

Co-firing, which is defined as simultaneous combustion of different fuels in the same furnace, provides one option to reduce fossil fuel use and related emissions. This is probably the most popular approach to the co-utilisation of biomass materials with fossil fuels. In particular, the co-firing of solid and liquid biomass materials and waste-derived fuels (WDF) in large coal-fired power plants has been growing in popularity. Utilisation of solid biofuels and WDF with coal sets new demands for boiler process control and boiler design, as well as for combustion technologies, fuel blend control, and fuel handling systems. Similarly biogas upgraded to biomethane can be co-fired with natural gas or added to natural gas pipelines; however this type of application was not addressed at this workshop.

The characteristics of biomass and WDF are very different from those of coal. The proportion of volatile matter in wood-based biomass is generally close to 80%, whereas in coal it is around 30%. This means that with biomass the fuel char levels are lower, and the resultant chars tend to be more reactive in combustion processes. Many biomass and WDF materials tend to have lower ash, nitrogen and sulphur contents than coals. This can have an impact on the ash discard levels and the levels of gaseous and gas-borne emissions. Most biomass and WDF materials have lower calorific values and bulk densities than coals, and this has significant impacts on fuel storage volume requirements and on the performance of volumetric feeding devices.

The basic properties of a number of solid fuels have, for instance, been compared in a simple ranking scheme, which has been reproduced in Figure 2. This illustrates the wide range of fuel types that are of industrial interest and ranks them in terms of their basic value as fuels and their degree of difficulty in thermal processing plants.

The co-firing of wood-based and other clean biomass materials has been demonstrated technically and is in commercial operation in a number of large coal-fired boilers, particularly in Europe and North America, but also elsewhere. In general, the co-firing ratios have been low, i.e., less than 10% on a heat input basis, and the impacts on the boiler performance have been modest.

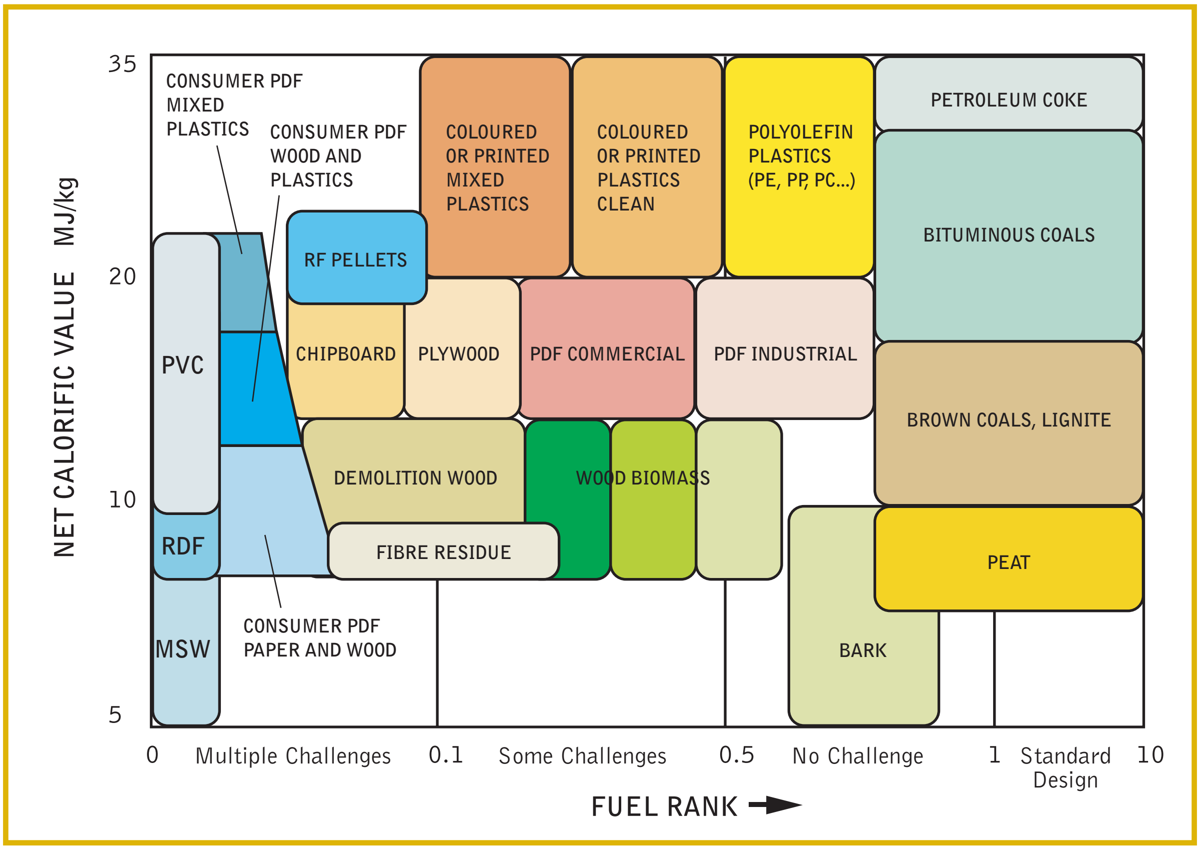


Figure 2: *Fuel rank - Influence of fuel characteristics on boiler design. (PVC: Polyvinyl Chloride; RDF: Refuse Derived Fuel; MSW: Municipal Solid Waste; PDF: Plastic Derived Fuel; RF: Recovered Fuels) [2]*

PRESENTATIONS

The workshop consisted of seven presentations from invited speakers, mostly from outside the IEA Bioenergy Implementing Agreement [3]. The main points emphasised by the speakers are summarised below.

Presentation 1: 'Global operational status of co-firing biomass and waste with coal: Experience with different co-firing concepts and fuels', by Jaap Koppejan, TNO MEP, the Netherlands.

Jaap Koppejan summarised the comprehensive review of co-firing by IEA Bioenergy Task 32. Full results are available at www.ieabcc.nl. The review included consideration of:

- the key drivers for incorporating biomass in existing coal-fired plants;
- the different types of biomass and their characteristics;
- the implications of biomass use in coal boilers - e.g., cost, efficiency, ash deposition; and
- public perceptions of co-firing.

Over 150 coal-fired plants globally have experience with co-firing, at least on a trial basis. As of 2004 there were approximately 40 commercial systems worldwide which in total have replaced 3.5 Mton of coal and hence avoided the release of around 10 Mton of CO_2. However, the estimated potential to replace coal is about 30 times higher. The speaker concluded that, although industrial experience with biomass co-firing is expanding rapidly in Australia, Europe, and North America, there are still a number of technical areas which require further development work and there are non-technical barriers to overcome.

Biomass Co-firing Concepts

- Direct co-combustion in coal fired power plants
- Indirect co-combustion with pre-gasification or other thermal pretreatment
- Indirect co-combustion in gas-fired power plants
- Parallel co-combustion (steam side integration

PowerPoint slide from Presentation 1. Source: J. Koppejan.

Presentation 2: 'A review of the recent experience in Britain with the co-firing of biomass with coal in large pulverised coal-fired boilers', by Bill Livingston, Mitsui Babcock, Renfrew, UK.

Bill Livingston introduced British Government policy in this area and specifically the Renewables Obligation which is the main financial instrument promoting the implementation of renewable energies. He described the biomass fuels, both imported and indigenous, being used in Britain for co-firing, and the technical choices and experience of the power plant operators. In most cases, the biomass is pre-mixed with the coal at low co-firing ratio, and the mixed fuel is then processed through the installed coal handling milling and firing equipment. In a small number of power plants, direct biomass firing systems, i.e., by-passing the coal mills, were also being installed. Overall, the experience of co-firing has been relatively good, with few significant impacts on plant performance. He concluded that the Renewables Obligation had been successful in promoting co-firing activities and that, within a three year period, all of the coal-fired power plants had become active in pursuing biomass co-firing. This is likely to continue. In a broader context and taking a longer term view, Dr Livingston concluded that biomass co-firing represented the most efficient, lowest cost and lowest risk means of generating electricity from biomass.

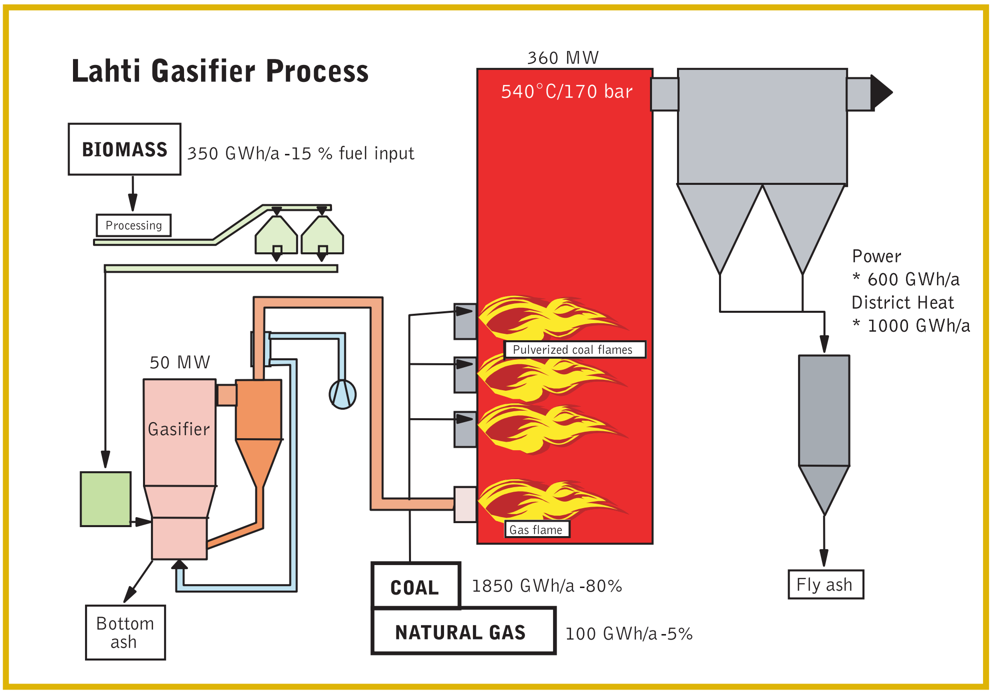
Conclusions

- Direct co-firing projects are being developed in British coal-fired power plants as a means of increasing the co-firing ratio.
- A number of approaches are being adopted, depending on the fuel and the preferences of the operator, viz;
  - Direct injection to the furnace, with no combustion air
  - Dedicated biomass burners
  - Injection of the biomass into the pulverised coal pipework or at the burner
- No single preferred solution has been identified, as yet.

PowerPoint slide from Presentation 2. Source: W.R. Livingston.

Presentation 3: 'Foster Wheeler biomass gasifier experiences from Lahti and Ruien and further cases for difficult biomass and RDF gasification', by Timo Anttikoski, Foster Wheeler Energia Oy, Finland.

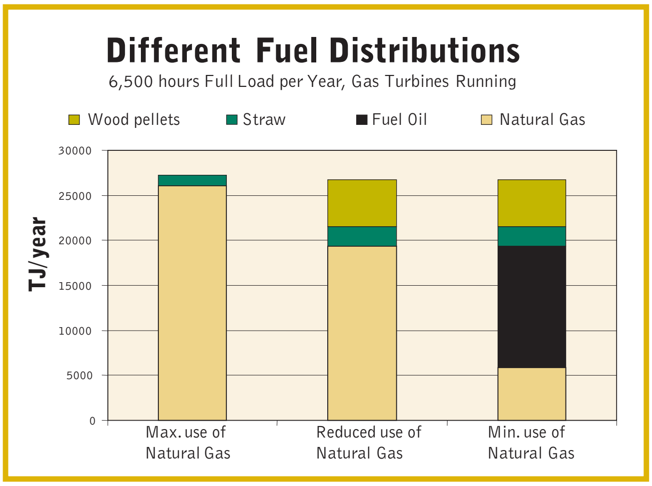
Timo Anttikoski presented the successful history of Foster Wheeler with gasification technology in circulating fluidised bed gasifiers, and described in detail the successful implementation of indirect co-firing at the plants of Lahti, Finland, and Ruien, Belgium. He then presented results of Foster Wheeler's experiences with difficult (but relatively cheap) biomass fuels such as straw and derived fuels. He concluded that the indirect co-firing based on gasification was reliable and significantly reduced the ash-related problems of these difficult fuels.



PowerPoint slide from Presentation 3. Source: T. Anttikoski.

Presentation 4: 'Utilisation of straw and wood in large-scale power plants', by Per Ottosen, Energi E2 AS, Denmark.

In his presentation Per Ottosen described the fuel flexibility and main operating performance and characteristics of the Avedøre 2 plant that the Executive Committee had the opportunity to visit on 24 May 2005. Avedøre 2 is a new combined heat and power (CHP) plant that supplies electricity and district heating to consumers in the Copenhagen area. It uses the best available techniques, resulting in high efficiency and excellent environmental performance. This CHP plant can burn natural gas, heavy fuel oil, and biomass as straw and wood pellets, using this very high fuel flexibility to optimise economic and environmental outcomes.



PowerPoint slide from Presentation 4. Illustration of fuel flexibility. Source: P. Ottosen.

Presentation 5: 'Status of biomass co-firing in Belgium', by Yves Ryckmans, Laborelec, Belgium.

Yves Ryckmans focused on the relatively complex system of green certificates and tariffs that exist in Belgium and on the biomass fuel supply chains to the power plants. Various feedstocks are used in different Electrabel plants, with a total of over 300,000 tonnes used to produce around 43 MW_e in 2004 and substantial growth forecast for 2005 and 2006. He emphasised that for countries like Belgium much of this feedstock has to be imported, and clean biomass is preferred. If the biomass is classified as 'waste' there are issues with obtaining a permit and it is likely that retrofitting for co-firing will be more expensive. The green certificates enable power plants to remain profitable, since they provide income to compensate for the higher biomass fuel costs. Proper attention to public perception and acceptance issues, and a realistic approach to environmental controls and other regulatory matters, are important to the success of biomass co-firing projects.

Electrabel Strategy
Which kind of Biomass ?

Today's Basket :

Olive Cake :	1 kg - 1.3 kWh
Wood Dust :	1 kg - 1.8 kWh
Wood Chips :	1 kg - 0.8 to 1.5 kWh
'Pellets' (clean wood) :	1 kg - 1.8 kWh
Sewage Sludge :	1 kg - 1.0 kWh
Coffee grounds :	1 kg - 1.6 kWh

PowerPoint slide from Presentation 5. Source: Y. Ryckmans.

Presentation 6: 'Co-firing in the Netherlands: The need for a secure supply', by Martijn Wagener, Essent, the Netherlands.

Essent is a utility that actively promotes co-firing. Martijn Wagener presented the issues Essent is facing in ensuring long-term supply of biomass at adequate volumes and reasonable cost. They have developed a control and certification system (Essent Green Gold) to ensure sustainability and traceability of biomass throughout the entire supply chain. In 2005, an independent foundation was established to develop and increase the use of this Green Gold label. The company believes that co-firing is one of the most cost-effective ways to produce sustainable power, using existing infrastructures. It also paves the way for a sustainable infrastructure for large-scale stand-alone bioenergy plants based on new technologies and a developed bioenergy trade. However, due to recent loss of incentives, the present issue for co-firing in the Netherlands is not the need for a secure supply but for a secure demand.

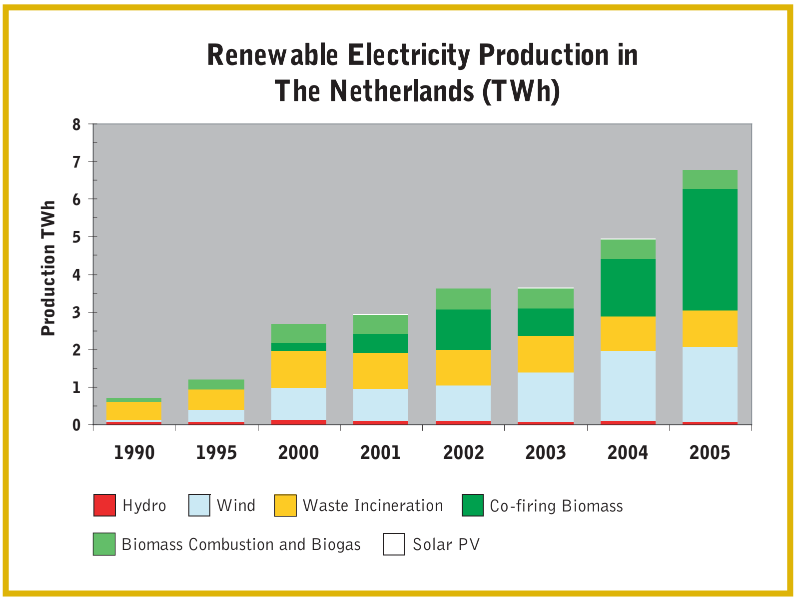
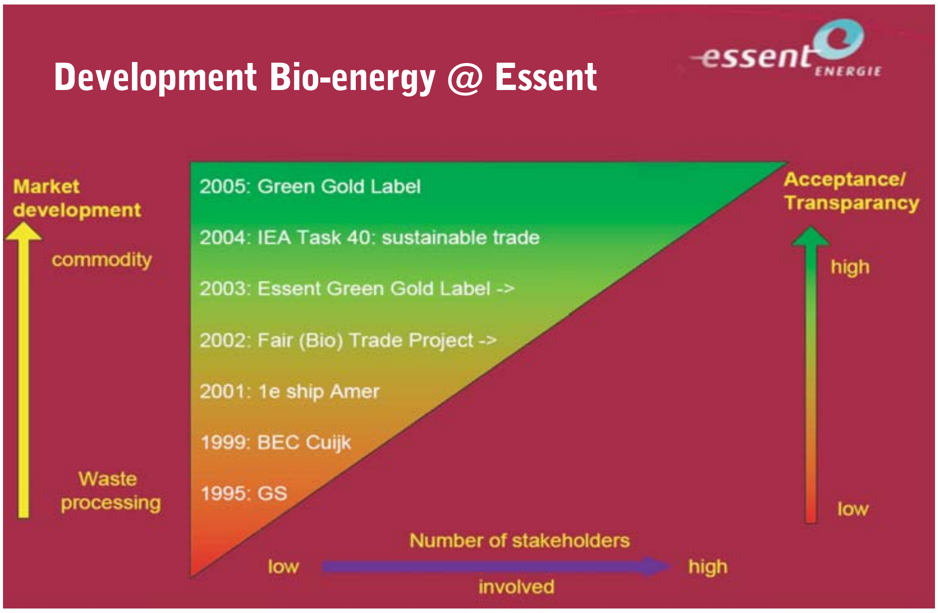


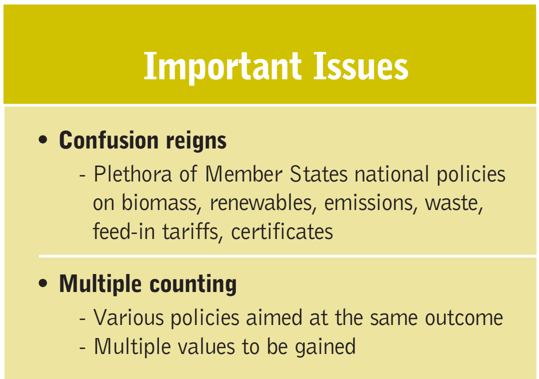
Figure 3: *Renewable electricity production in the Netherlands. (Source K. Kwant, SenterNovem).*



PowerPoint slide from Presentation 6. Source: M. Wagener.

Presentation 7: 'Environmental markets for co-firing of biomass', by Adrian Reeves, IT Power, UK.

Adrian Reeves presented the global environmental markets as a means of promoting the reduction of greenhouse gas emissions. The emissions can be reduced either directly through the adoption of more efficient or less environmentally harmful processes, or indirectly through the promotion of renewable energy technologies to replace more traditional fossil-fuelled power generation. He analysed the three major environmental markets from which co-firing facilities in EU Member States could benefit, i.e., emission trading schemes, green certificates, and national energy efficiency schemes. The focus of his paper was the policy and market interactions, analysed and discussed from a UK perspective. He concluded that the UK Government regards co-firing as an interim measure for meeting commitments under the Kyoto Protocol, with incentives provided primarily to help grow the biomass fuel supply chain within the UK.



PowerPoint slide from Presentation 7. Source: A. Reeves.

Biomass and coal fuel storage facilities at the Dolna Odra co-firing plant in Poland. Courtesy I. Obernberger, Bios-Bioenergy, Austria

DISCUSSION OF KEY POINTS

The key points from the above presentations and subsequent discussions can be summarised under the following headings.

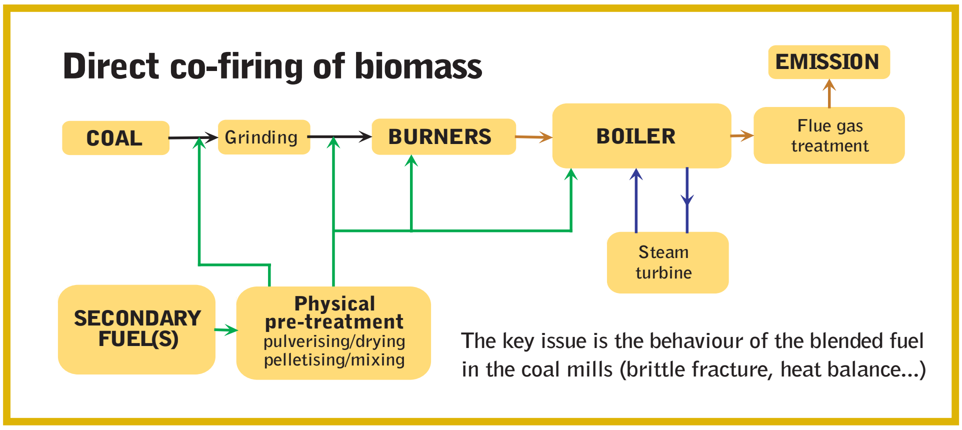
General characteristics of co-firing

Compared to dedicated biomass power plants, co-firing with biomass has certain advantages. These are:

- lower investment costs because of the use of existing infrastructure (e.g., boiler and power cycle);
- in modern coal-fired power plants co-firing has higher electrical efficiency made possible by scale effects; and
- demand for biomass in significant quantities helps to establish fuel supply chains.

There is a range of different technologies available but at present, due to the modest proportion of biomass in the fuel, most systems involve direct co-firing (only five installations use indirect co-firing via gasification). Though the technology is relatively simple there are still a number of relevant R&D projects under way to:

- increase the proportion of biomass being used particularly for new advanced coal-fired boilers;
- increase fuel flexibility (better handling, storage, and blending);
- overcome striated flows due to the different burning rates of coal and biomass;
- avoid deactivation of Specific Catalytic NO_x Reduction (SCR) catalysts;
- minimise fouling resulting from the higher alkaline content of some biomass;
- minimise corrosion resulting from the higher chlorine content of some biomass; and
- ensure the mixed biomass/coal ash from co-firing can be used e.g., in building infrastructure (concrete) to safeguard the economic viability of the coal plants.



PowerPoint slide from Presentation 1. Source: J. Koppejan.

Initiating co-firing in existing plants

Co-firing can make use of the existing electricity generation and distribution infrastructure and is therefore often the cheapest and quickest method to extend bioenergy use. Biomass can be co-combusted in old inefficient as well as modern high-performance coal-fired power plants. Often old inefficient plants have lower requirements for biomass feedstock quality than modern plants and can be converted for co-combustion more simply. However, many governments wish to see inefficient coal plants closed for environmental reasons and therefore see a risk that policy instruments aimed at increasing bioenergy may instead result in increasing the lifespan of these old coal-fired plants. This potential risk can be addressed by careful design of the policy instruments.

When starting up new applications and/or facilities the first step is to identify suitable feedstock supplies. Initially biomass is fed over the existing coal belt and co-milling is possible up to 5% on an energy basis. However, it is strongly recommended that coal and wood dust are not mixed in the mill, because of fire/explosion problems. When the commissioning has been successful, the power plant owners will have to make a decision to consider specific milling with dedicated burners for biomass, which will lead to major modifications and investment. Alternatively, it is possible to feed the milled biomass into the coal pipe-work but additional process control will be required. So when space around the burner permits, specific burners might be advantageous. Ultimately, the logistics and fuel characteristics will be limiting, and for difficult fuels one has to consider gasification as a pre-treatment.

The role of gasification

Gasification to produce a clean fuel gas for indirect co-firing is particularly useful for difficult fuels. This approach involves significantly higher levels of capital investment than most of the direct co-firing options, but can offer a greater degree of fuel flexibility and can reduce the impacts of co-firing on the host coal boiler e.g., fouling or SCR deactivation. WDF are likely to be more readily available because clean biomass supplies are in higher demand and often more expensive. Furthermore, as tighter waste/landfill regulations are introduced, WDF will be more prominent.

Lahti fuel conveyor. Courtesy T. Anttikoski.

At present gasification as a pre-treatment is successfully applied at Lahti in Finland, and at Ruien in Belgium. Multiple fuel sources including solid recovered fuel, RDF, bark, and wood are used in Lahti, up to 15% energy input, with special burners. Dry wood dust is used in Ruien, up to 11% energy input. The accumulated experience in Lahti has shown that a multi-fuel operation does not increase emissions from the installation.

The EU Waste Incineration Directive includes stricter emission regulations after 2005, and these will be difficult to comply with in old, coal-fired power plants without additional flue gas treatment equipment.

The gasification technology also offers the potential to replace natural gas by fuel gas or syngas in existing highly efficient Combined Cycle plants.

Percentage of biomass in co-firing

In direct co-firing applications in large power plants by pre-mixing and co-milling, the co-firing ratio is normally less than 10% on a heat input basis. The constraints are usually associated with:

- fuel availability, fuel handling and storage capacity;
- throughput limitations associated with the ability of the installed coal feeders and mills to process the mixed fuel; and
- coal boiler draft plant limitations, and other impacts.

At such low co-firing ratios, the risks of significant impacts on the coal boiler performance are small in most cases.

A smaller number of plants are co-firing at higher levels by direct firing pre-milled biomass materials. There may be restrictions on the types of biomass that can be co-fired in this way, mainly because of concerns about ash-related impacts on the performance of the host coal boiler and the market acceptance of the biomass/coal ash.

A direct firing system: pre-milled biomass is pneumatically conveyed and injected into the pulverised coal pipework. Courtesy W. Livingston and Drax Power Ltd, UK.

The Avedøre 2 plant in Denmark demonstrates that a very high proportion of biomass (30% of energy input) may be used in co-firing as both straw (150,000 t/yr) and wood pellets (300,000 t/yr). The catalysts have to be chemically washed four times per year to reactivate the SCR used for ammonia reduction. Presently Electrabel is rebuilding a power plant in Awirs, Belgium, (downsizing from 125 to 80 MW_e) where the utility aims to achieve 100% replacement of coal by using wood pellets in existing modified mills.

Policy instruments

Technology-neutral policy instruments requiring an increased proportion of renewables tend to promote co-firing. The reason for this is the technology's high degree of cost efficiency and ease of incorporation into existing power production systems. The UK has used Renewable Obligation Certificates (ROCs) as one way to encourage coal-fired power plants to co-fire biomass. This is largely seen as an intermediate approach in ensuring a market for energy crops in the short to medium term. Increasing proportions of energy crops in total biomass input for co-firing will be phased in from 2009, and after 2016 no further ROCs will be available to co-firing so that stand-alone biomass facilities face less competition.

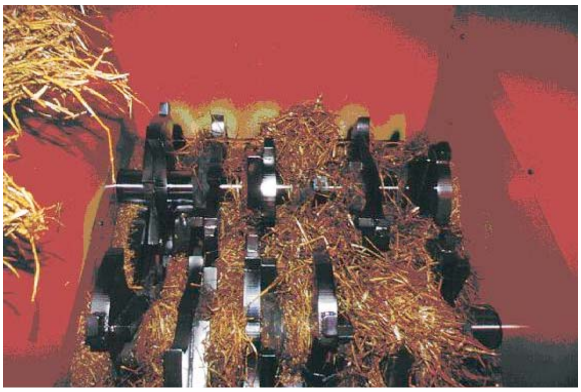
Energy producers in the various countries have responded to their specific policy frameworks and country-specific circumstances in different ways. None-the-less, care must be taken to avoid overly complex policy mechanisms and lack of transparency, as well as overlapping policy instruments and possible 'multiple counting'. In addition, issues of environmental integrity are now being addressed and documentation such as 'guarantee of origin' for biomass feedstocks is required in some countries to certify the sources and their sustainability.

Bioenergy is often promoted as a substitute for fossil fuels in order to meet climate change commitments, since biomass is considered to be CO_2-neutral. Given appropriate choices of fuels, boiler design, and operation, co-firing can certainly lead to a reduction in both traditional pollutants (SO_X, NO_X, etc.) and net greenhouse gas (CO_2, CH_4, etc.) emissions.

Biomass supply

Delivered biomass costs are often higher than coal, particularly for dedicated feedstocks for energy purposes, i.e., fuels that are not by-products or waste. Herbaceous biomass, particularly agricultural residues and annual energy crops, is more difficult to handle and blend, and the high alkali and ash content tend to cause fouling and SCR deactivation. These may be moderated by reducing combustion temperature or washing catalysts. Biomass derived from MSW can be even more challenging, but supplies may be cheap and plentiful.

There is a general preference for those biomass materials that are relatively dry, can be stored for long periods without significant dry matter losses or deterioration in quality, and which can be handled using conventional equipment. Baled materials have been utilised for co-firing, however the relatively high capital costs of the specialised bale handling, storage and pre-processing equipment has been a significant barrier to the wider use of these materials. The preferred fuel for co-firing is wood pellets due to consistent quality and hence providing reliability for the utility operator. However, wood pellets are probably the most expensive renewable solid fuel and therefore a balance has to be struck between plant operational reliability and economy.



Straw shredder at Studstrup power plant. Courtesy Elsam Engineering, Denmark.

Currently, the delivered prices for the majority of clean biomass materials suitable for co-firing are of the order of 3-5 times those of globally traded coals. In most cases, this means that co-firing activities are only commercially attractive to power plant operators if significant additional incomes from the generation of electricity from renewable sources are available. Some wastes and recovered materials can have lower delivered costs, however they commonly also have higher levels of ash and of a number of the prescribed pollutant species, and the co-firing of these materials may be specifically excluded from government policy instruments aimed at encouraging renewable energies.

Dumping wood chips on a coal conveyer before the mills. Courtesy Delta Electricty, Australia.

Feedstocks have been sourced from around the world for both trials and commercial operations. Electrabel source different biomass materials from various countries - not only Europe but also North and South America, Africa, and the Middle East. However, although this is important for energy security and the diversification of energy supplies, it will have to be managed under internationally acceptable sustainability criteria. This evidence of increasing interest in the establishment of an international trade in biomass fuels is also reflected in the Essent partnership with SenterNovem and the Ministry of Economic Affairs in the Netherlands, which has successfully launched a new Task within IEA Bioenergy 'Sustainable International Bioenergy Trade: Securing Supply and Demand'. It has the vision of a global commodity market in bioenergy. The expanding membership of the Task indicates strong interest in the topic.

IMPLICATIONS FOR BIOENERGY DEPLOYMENT

General

Co-utilisation of biomass with coal is of interest primarily among countries with policies which promote the substituting of fossil fuels for electricity production. There is considerable potential for increasing the co-utilisation of biomass with coal. Biomass co-firing could theoretically replace about 14% of the fossil fuel currently used globally for power generation. This represents about 2% of the total fossil fuel consumption in the world. Although this is significant it represents only a small fraction of what is globally intended for solid fossil fuel replacement through biomass. Therefore, besides realising the co-firing potential, the efforts to further develop stand-alone biomass options have to be continued and strengthened.

Technology

- The most cost-efficient bioenergy applications are often those which can utilise the existing infrastructure or aggregated biomass resources of other industries, or where energy products are by-products in processes for higher value products.

- Co-utilisation of biomass with fossil fuels makes use of the large-scale power plant's infrastructure and high electrical conversion efficiency. As a result co-utilisation in modern plants is normally substantially more competitive than dedicated bioenergy power plants, which usually are small-scale systems.

- Large-scale power plants tend to have less opportunity for heat recovery, so while electrical efficiency is high, overall energy efficiency may not be as high as in smaller CHP plants where both heat and power can be utilised.

- The technology is available to utilise many different types of biomass. Clean wood pellets pose few challenges for direct co-firing and may be the easiest and most flexible option. Other fuels, e.g., waste-derived ones, are more challenging, but greater availability and lower costs could justify the additional investments required.

- Compared to most other forms of bioenergy, co-utilisation of biomass in modern highly efficient CHP and power plants is commercially, technically, and environmentally an attractive solution for countries that wish to increase the proportion of renewable electricity. However, as for all other renewable energy sources this too is dependent on policy instruments.

Policy

- There is a considerable variation among governments in their attitudes to co-firing. Much of this variation can be explained by differences in techno-economic conditions. However, some of the variation can only be explained by differences in non-technical barriers, e.g., public and political acceptance, etc.

- It is important that policy instruments aiming to support and increase use of renewable energy sources do not support old, uncompetitive, and environmentally damaging coal technologies. Policy instruments supporting co-firing of biomass should be limited only to modern clean coal technology.

- Imported biofuels are improving energy security due to diversification of energy suppliers. However, implementation of worldwide trade of biomass or refined biofuels (e.g., pellets or bioethanol) requires a careful assessment of the sustainability of the complete chain.

Market development

- Co-utilisation of biomass with fossil fuels has the potential to utilise large quantities of biomass, thereby driving the development of feedstock supply infrastructure. If development is focused primarily on modern highly efficient power plants, the effect on feedstock infrastructure may be most notable on the pellets market and in the future on pellet production from short-rotation coppice.

- Maximising the useful energy derived from limited biomass supplies is the ultimate goal, therefore dedicated or stand-alone bioenergy technologies that result in high efficiency can contribute to distributed generation. Co-utilisation should be considered alongside other bioenergy technologies and services in order to optimise overall energy efficiency.

- Until recently co-firing of biomass with coal has been the most attractive scenario for co-utilisation of biomass with fossil fuels; however, the recent increase in the cost of oil and its effect on transport has put great attention on biofuel blends in diesel and petrol. The second-generation of biofuels is close to commercial demonstration and in the medium term it can be envisaged that the market development for co-firing may be restricted due to competition for resources with the market development for second-generation biofuels. Biogas co-utilisation with natural gas is an attractive option but its market development may be limited and it is not foreseen that in the short to medium term there could be any competition for resources with either the co-firing market or the second-generation biofuels market.

Biomass fuel storage facilities at the Dolna Odra co-firing plant in Poland.
Courtesy I. Obernberger, Bios-Bioenergy, Austria.

REFERENCES

[1] **IEA.** 2005. Key World Energy Statistics. IEA, Paris, France.

[2] **Anon.** 2003. Biomass Co-firing - An effective way to reduce green house gas emissions, EUBIONET, European Bioenergy Networks, ALTENER Programme, http//eubionet.vtt.fi

[3] **Anon.** 2005. Presentations to the ExCo55 Workshop 'Co-utilisation of Biomass with Fossil Fuels', 25 May 2005, Copenhagen, Denmark. Available at: www.ieabioenergy.com then click on 'Workshops'.

ACKNOWLEDGEMENTS

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FURTHER READING

Anttikoski, T., Palonen, J. and Eriksson, T. 2005. Foster Wheeler biomass gasifier experiences from Lahti and Ruien and further cases for difficult biomass and RDF gasification. Available at: www.ieabioenergy.com then click on 'Workshops'.

Koppejan, J. and Baxter, L. 2005. Global operational status on co-firing biomass and waste with coal: Experience with different co-firing concepts and fuels. Available at: www.ieabioenergy.com then click on 'Workshops'.

Livingston, W.R. 2005. A review of the recent experience in Britain with the co-firing of biomass with coal in large pulverised coal-fired boilers. Available at: www.ieabioenergy.com then click on 'Workshops'.

Ottosen, P. 2005. Utilisation of straw and wood in large-scale power plants. Available at: www.ieabioenergy.com then click on 'Workshops'.

Reeves, A. 2005. Environmental markets for co-firing of biomass. Available at: www.ieabioenergy.com then click on 'Workshops'.

Ryckmans, Y. 2005. Status of biomass co-firing in Belgium. Available at: www.ieabioenergy.com then click on 'Workshops'.

Wagener, M. 2005. Co-firing in the Netherlands: The need for a secure supply. Available at: www.ieabioenergy.com then click on 'Workshops'.

IEA Bioenergy

IEA Bioenergy assists member countries to expand the use of sustainable bioenergy systems through facilitation, coordination, and demonstration activities. This is accomplished through cooperative research and information exchange, leading to the commercialisation and deployment of bioenergy technologies.

Further Information

IEA Bioenergy website:
www.ieabioenergy.com

IEA Bioenergy Secretariat
John Tustin
PO Box 6256
Whakarewarewa
ROTORUA
NEW ZEALAND
Phone: +64 7 348 2563
Fax: +64 7 348 7503
Email: jrtustin@xtra.co.nz

The turbine and generator units at Avedøre 2. Courtesy T. Scott Lund, Energi E2, Denmark.

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