The future for biomass pyrolysis and gasification: status, opportunities and policies for Europe

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WORKSHOP TOPIC	CHAIR AND RECORDER
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Fast pyrolysis	AV Bridgwater and M Gronli
Waste	N Abatzoglou
Syngas for synfuels	CN Hamelinck and RL Bain
Power Production by engines, turbines and fuel cells	P Thornley and D Chiaramonti
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LEGAL NOTICE

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INTRODUCTION

The EC has supported research, development and demonstration in biomass pyrolysis and gasification for 20 years, but the rate of advancement and implementation to meet the short term and long targets for greenhouse gas mitigation has been disappointing. An Expert Meeting was organised under Part C (Direct Subventions) of the Work Programme for SAVE and ALTENER Calls 2001-2002 to assist the European Commission to develop policies in the area of renewable energy sources. The purpose of the meeting was to review the achievements to date in the fields of biomass pyrolysis and gasification and to explore the ways in which the European Commission can encourage the implementation and penetration of these technologies.

The meeting provided a timely and authoritative review of the status of the technologies and particularly addressed the concerns over the rate and extent of implementation and penetration of the thermal biomass conversion processes of pyrolysis and gasification.

PROGRAMME

The meeting included formal presentations by invited speakers, experts in the field, workshops and discussions.

An up-to-date review was presented of the technology status and future directions of the pyrolysis and gasification of biomass and waste. The aim of the overview presentations was to provide a framework for the workshop discussions.

Case-studies were selected to set the scene for the workshops and particularly focused on the problems encountered in industrial development and implementation, how they had been solved, highlighted any problems that remained and how they are being addressed. The objective was to provide guidance to the participants as to the technical and non-technical barriers associated with commercial development and implementation of bio-energy systems and to provide practical experience to draw on in the workshop sessions.

Poster presentations provided background material and supported the deliberations of the workshops, and as such were an essential component of the workshops as well as being snapshot of the research, development and demonstration work that is currently in progress.

Workshops were selected from a survey of the delegates prior to the meeting to address topical problems under the chairmanship of an expert in that area, with a particular focus on definition of policies for encouragement, implementation and penetration of these important technologies.

- Technical Barriers - Gasification
- Technical Barriers - Pyrolysis
- Technical Barriers - Waste
- Syngas for synfuels
- Power production by engines, turbines and fuel cells
- Economics

Reports from these workshops provide the basis for the rest of this report. The full proceedings from the Meeting have been published by CPL Scientific Press.

GASIFICATION

Introduction

Gasification of biomass and waste has a long history and has been seen as an attractive alternative to produce power and heat. However, despite many achievements it can only be considered to be commercial for heat applications. The objective of the workshop was to identify and to prioritise what is needed to accelerate the implementation of gasification technology.

A few gasifiers have already been in operation for twenty years and a number of gasification processes are under industrial development at pilot and demonstration scale. Gasifiers are available from Foster Wheeler and Bioneer in Finland, Lurgi in Germany, Vølund in Denmark, TPS in Sweden, PRM Energy in the USA and Repotec in Austria. In addition there is extensive research and development at universities, research institutes and companies around the world. Different technologies are more suitable for different scales of operation as shown in Figure 1.

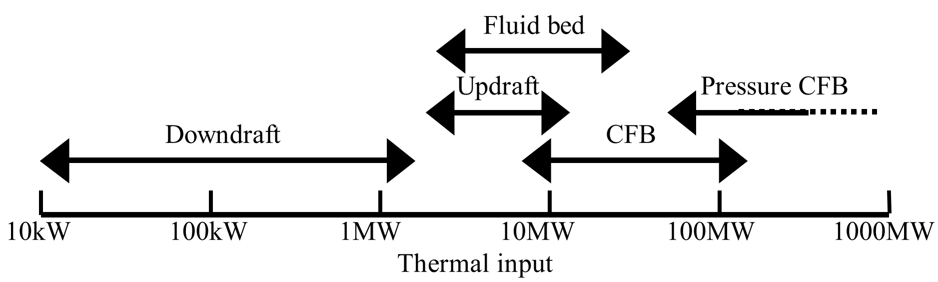

Figure 1: Gasifier Concepts

A range of feedstock is available for gasification and varies from clean biomass to waste fuels containing different amounts of ash, alkaline and emission precursors like N, Cl and S. A wide range of applications has been developed and demonstrated for (co)-firing in boilers/furnaces, gas engines and combined cycles. For some applications, it is important to increase gas-heating value. Low heating value gas has some impact on power generation, which has to be properly considered such as power de-rating and flame stability.

A gasification system consists of four main stages and each area was discussed and reviewed with respect to technical obstacles in the first part of the workshop:

- Feeding
- Gasifier reactor
- Gas cleaning
- Utilisation of combustible gas

The second part of the workshop was dedicated to the discussion of non-technical obstacles.

Technical obstacles

Feeding

Feeding is important and especially the feeding of pressurised systems is seen as problematic (mechanical problems, gas tightness problems, etc). Some genius level engineering solutions are required in this area.

Low-pressure gasifiers can adopt a lot of the technology developed for combustion of biomass.

Gasifier reactor

In addition to the development of rather fuel specific gasifiers, there is currently a strong need for fuel flexible gasifiers that are also able to convert difficult fuels, e.g. high alkali and high ash content fuels. Scale up issues should be considered carefully. There is a trend to separate combustion, pyrolysis and/or reduction zones by multi-step gasification. Also design are under development for more difficult type of fuels.

Modelling

The reactor design of gasifiers is not optimised yet and can be improved. In analogy with the development of biomass combustion in the past, a major tool to achieve this is physical and mathematical modelling.

Design and modelling of fluid bed gasifiers have to be done in close co-operation between manufacturers, and universities. However there is a confidentiality problem in providing commercial data and funding is not being spent sensibly in supporting modelling studies when real data cannot be provided. As a result available good models for fluid bed gasification seem to remain unused.

Good models are not available to show what is going on with particles during updraft and downdraft gasification such as shape changes, and flow through the channels between particles. Models and fixed bed tunnelling diagnostic techniques are needed to identify what is happening with particles during their way through the bed.

Heating value

As a way to increase the heating value of the gas, it was suggested to increase the use of wastes e.g MSW as a feedstock for gasification, although an increase in gas heating value is not necessary for all applications. The most important issue is about the efficiency of the gasifier and not the heating value of the product gas.

Gas cleaning

Micropollutants

The consequences of the presence of micropollutants present in biomass and waste, e.g. metals, organo-metals etc., are unidentified and should not be underestimated.

Economic demonstration

Gas cleaning for Cl, Hg, S, N, metals, etc. seems to be sufficient reliable at the moment but its cost should be considered. Niche markets have to be found and further developments should be more towards commercial solutions. This requires economical demonstration plants for long term testing, which should be done in co-operation with research and lab scale experiments, All emission problems have to be solved, before commercial application, even for difficult fuels. Many different gas cleaning devices are developed and applied like (multi)cyclones, solid bed filters, bag filters, scrubbers, rotating particle separators, tar crackers, ESP, etc. It was recommended to conduct a technical, socio-economic comparison of the different options.

Hot gas cleaning

In addition there should be more emphasis on hot gas cleaning such as the removal of sulphur by liquid Ti (99.5 % recovery) or a Zn-absorber, the injection of lime, etc.. However, solutions for hot gas cleaning must be cost effective and not too fancy.

Ash

Another important point of concern is the quality of the ash and tendency for sintering and ash melting.

Tar removal

Tar removal or cracking is a major point of concern in gasification en still needs focus. Nickel catalyst are likely to be used increasingly in the future for tar cracking, although the technology is currently only in the laboratory. Table 1 summarises the main options for removing or cracking tars.

Table 1 Tar conversion and elimination concepts

Internal thermal	**addition of oxygen and steam**
Ultra-high gasification temperature	oxygen and steam
Physical separation	e.g. wet scrubbing, adsorption, centrifugation
Internal catalyst	e.g. nickel or dolomite bed
External catalyst	secondary reactor with e.g. nickel or dolomite
External thermal	secondary reactor with addition or oxygen or air
External reverse flow	secondary reactor with addition of air or oxygen

Filters

Filters like conventional bag house filters have been successfully tested for particle separation at reasonably high tar contents for fluidised bed gasifiers. When a sorbent is used, there is a good reduction in HCl levels in the filter.

Condensates

Condensation of water and tar vapours causes many problems in downstream equipment. Two solutions are under development: (1) avoidance of producing condensate by keeping the temperature above the dewpoint and (2) cleaning of condensate and/or scrubbing water and recycling of tar into the gasifier.

Heat exchangers

Corrosion and fouling in hot gas heat exchangers is still a problem. Causes need to be identified and knowledge shared.

Applications

The specifications and emissions consequences of prime movers are poorly understood and work is needed to both better define (realistic) specifications and control emissions.

At small scale there are no problems in engines with thermal NOx due to excess air. Fuel NOx is taken out with wet scrubbing of the gas. Instead high emissions of unburnt components such as CO and hydrocarbons are a difficult problem. Catalytic aftertreatment of flue gas is necessary if emission limits based on the waste incineration directive are applied. There are arguments which explain that this is a wrong perception.

Gas turbine experience at Värnamö has shown that vapour phase tar is not a problem in gas turbine clean up. At high pressure/high temperature removal of NH_3 is currently not available.

Non-technical obstacles

Commercial aspects

Information can be derived from insurance companies, banks and project developers. Thornley and Wright have presented a valuable overview of important items that should be considered during commercialisation of new thermal technologies. Particularly important items include reliability, availability, and ease of operation (staffing need and need for automatic operation without staff for small plants).

An EPC contractor is often requested by the customer to avoid gaps in the total contract scope.

CHP is a good opportunity for increased efficiency and lower fuel costs for power.

Incentives

At current biomass and capital cost levels, incentives are essential for a commercially viable biomass projects. Successful examples of incentives include Swedish practices:

- CO_2 tax for heating applications means biomass is commercially very attractive,
- NO_x fee. Combustion plants with high emissions pay plants with low emissions of NO_x.

These have led to a rapid increase of biomass and steadily lower NO_x-emissions based on extensive RD&D.

Financial aspects of gasification projects that require consideration include:

- High initial investment
- Limited private investments
- Remuneration of CHP
- Feedstock availability
- Small subsidies are not stimulating
- Subsidies tend to decrease

Permitting procedures and emission limits are increasingly onerous but necessary:

- Complex, time consuming
- Unknown technology to authorities
- Strict emission limits from incineration
- No one common legislation

Health and safety impacts include:

- Which directive is valid to gasification
- Guidelines for safe operation and construction is needed
- Deforestation
- Fire and explosions
- CO poisoning
- Hot surfaces
- Air pollution
- Noise pollution
- Oil spill
- Water pollution
- Litter

Conditions for commercialisation

Gasification is considered to be close to commercial available. To be commercial, many conditions need to be fulfilled which are summarised below.

- Technology must be mature, based on proven prototypes and long-term duration testing
- Infrastructure must be adequate in particularly for a sustainable fuel supply
- There is a need for motivated and skilled labour at all levels
- Scale-up, demonstration, replication and optimisation is needed to commercialise the technology. Some are in favourite to talk about economy of numbers instead of economy of scale. In fact, such measure will improve the technology by learning from doing. Moreover, replication and optimisation will also reduce the capital costs
- Information and knowledge exchange is very important, like ThermoNet is proposing
- A loan finance for customers will help to reduce the risk for any first-of-its-kind installation
- There is a strong need for clear regulation on permitting procedures, emission standards, and other health & safety aspects
- There is a need for sustainable feedstock supply and remuneration of electricity and heat produced

Conclusions and recommendations

- Demonstration projects are quite risky and should ideally be made by companies with strong finances. In practice, companies that are willing to accept high risk often already have weak finances.
- CHP is a good opportunity for increased efficiency and lower fuel costs for power. But there are high capital costs for piping heat for district heating in combined heat and power systems. CHP is difficult economically and practically in old cities but should carefully be considered in new areas.

- The current strict emissions limits for combustion plants have to be seen as a baseline for new technology e.g. gasification although the difference in oxidizing and reducing atmospheres must be considered. New technology sometimes has an advantage over old technology with bad public reputation.
- At high pressure/high temperature removal of NH_3 is currently not available.
- Economical demonstration plant e.g. in niche markets is required for long term testing. Niche markets need to be identified and exploited in the short term.
- Greater co-operation between industry with such demonstration plants and research organisations through use of laboratory scale experiments would be beneficial for reducing costs and resolving problems. This would also improve the experiences of fundamental researchers.
- For hydrogen, more attention and work is needed on safety aspects including handling. Although many years ago town gas, a mixture of hydrogen and carbon monoxide, was delivered to every household and we all knew how to live with it.
- More emphasis is needed on hot gas cleaning; removing ammonia and sulphur from the hot gas and there are still opportunities to try new concepts.
- It is important and often essential to avoid repeating old mistakes by reading the literature. Wrong approaches have often been adopted because of lack of knowledge of previous work and results from that work, particularly in papers from 1970-2002. Much is already proven and disproven and re-inventing old problems lose time and money. Sometimes old tests should be repeated because they appear to be or might be wrong.
- Supercritical water may offer some useful opportunities.
- Modelling and optimisation can improve reactor vessels and design of gasifiers. Modelling in particular offers much promise for improved design and performance, but there is a problem with validation with data from companies due to confidentiality problems.
- Technology providers need to offer whole gasification plant, otherwise there will be gaps and omission in the performance guarantees. This is the reason why turn-key EPC contracts are important On the other hand the value of guarantees and even turnkey contracts is often overestimated. When problems occur, the customer is often the one that has the major burden.
- It is necessary to demonstrate that a local skilled workforce can operate gasification plants.
- There is a possibility in doing projects in stages if parts of the project have high risk and others low risk. The actual risk is minimised if the initial investment is small, then the potential loss will be small.
- It is important to calculate that the feedstock has to be paid for i.e. it has a cost, even if it can be obtained free initially to ensure there is sufficient profitability over the plant life.
- The question of defining the market and matching the availability of technology to that market is very important:
- Gas cleaning and tar cracking or removal and gas cleaning remain the largest problem in gasification,
- After many years of R&D, workshops and conferences, the bottleneck is still wider exploitation of gasification technology.

A number of important and fundamental questions were posed that could not be fully resolved, particularly:

- What do we want to use the biomass for in the future: energy and/or chemicals? This was considered in several workshops.
- After 15 years of extensive research and development and much funding, there are still only a few commercially operating plants: why?

FAST PYROLYSIS

The objective of the workshop was to identify and prioritise what is needed to improve the rate and extent of both penetration and success of fast pyrolysis technology into the market. A number of fast pyrolysis processes are under industrial development at pilot or demonstration scale or available, and these are aimed power, heat, fuel and chemicals, all of which have been shown to be feasible.

Feed materials

The importance of the provisions for the supply of feedstocks as forestry materials, energy crops and agricultural by-products and wastes are often underestimated. Long term contracts are important to ensure a secure supply of feedstock. Transport distance is an important consideration to minimise cost and environment impact and feedstock supply and logistics is important when scaling-up. The cost of feed, which is a major contributor to the cost of bio-oil, needs to be minimised. In particular the supply chain needs to be developed and harvesting and storage systems developed.

Wood residues, forest residues and bagasse are the most interesting short term feed materials. They are widely available, at low cost and with good performance in fast pyrolysis. Straw and agro residues are important in the longer term, but it should be noted that straw has low lignin but high ash content which might cause problems in pyrolysis and use of the bio-oil. Sewage sludge is a significant resource that requires new disposal methods and can be pyrolysed to give liquids. Biomass characteristics should not be a technical barrier in pyrolysis and gasification and most biomass can be successfully pyrolysed.

Feedstock preparation operations (handling, storage, drying, grinding) are similar to practises in chipboard production (typically 50-200 kt/y) and should not be a problem beyond the tight economic constraints that the energy sector has to meet. However, down-scaling of the commercial equipment used in the wood and pulp industries can be challenging both technically and economically.

Fast pyrolysis

Process development and operation is improving with higher quality and more consistent bio-oil being produced. In addition new technologies are reaching demonstration scale with well defined business plans from several companies. However, bio-oil for testing is in short supply. This is preventing long-term performance tests needed for evaluation as well as inhibiting the development of new applications.

Scale-up is an increasingly important issue as pilot and demonstration plants have to be commercially realised. Heat transfer is a critical area in pyrolysis as the pyrolysis process is endothermic and sufficient heat transfer surface has to be provided to meet process heat needs. It was suggested that limits in the short term might be around 100 ton/day, with modular construction of larger plants, although there was also a view that 100 t/d may also be the smallest economic plant size. Economically attractive operation requires low cost feed, large scale operation and technical development to improve performance and reduce costs. Fundamental studies to support reactor and process development are an essential ingredient for successful implementation and this is discussed below.

Bio-oil – pyrolysis liquid

Bio-oil aging should not be a problem since storing longer than 12 months is very unlikely and it should not be forgotten that fossil fuels also age. Phase separation is still seen as the major problem, usually caused by high feed moisture or mixed feed such as forestry residues with a high bark content. However, as companies gain more experience in operating larger-scale units and the fundamentals of pyrolysis process become better understood, this problem should diminish. Good bio-oil quality is a result of process optimisation. Though different feedstocks give oil of somewhat different properties, those liquids can be usually mixed. There was a consensus that the poor reputation of bio-oil was not justified.

Because bio-oil is so much different from petroleum fuels, it requires new standards that have to be developed. For example, bio-oil has low flash-point, but a high ignition temperature. Such differences cause misunderstanding and education and promotion (PR) is an important factor in the development of fast pyrolysis technologies. PR is important and pyrolysis must not be harmed by a negative image, which is where Networks such as PyNe can make a valuable contribution through promotion, training and dissemination of proper information. PyNe is working actively to resolve problems and address priority issues, such as applying for EC projects which has resulted in successful proposals to determine norms and standards for biomass derived pyrolysis liquids, and assess bio-oil toxicity.

Heat Applications

The heat market offers substantial potential but is highly dependent on costs in order to compete with fossil fuels. Bio-oil can substitute for Light Fuel Oil and Heavy Fuel Oil according to specifications. For example, the light fuel oil market in Finland is attractive for intermediate size boilers due to taxation, and burner development is active in Finland to support that market. Co-firing of bio-oil has been demonstrated in 350 MW gas fired power station in Holland, when 1% of the boiler output was successfully replaced. It is in such applications that bio-oil can offer major advantages over solid biomass and gasification due to the ease of handling, storage and combustion in an existing power station when special start-up procedures are not necessary.

Power Applications

Electricity is an attractive product for its relatively high value, ease of distribution and ease of adapting to local or national market specifications. In addition, the electricity market in Europe offers significant incentives, up to €0.1/kWh, for power gemerated from renewable resources. CHP offers the possibility of enhancing revenues and achieving high overall system efficiencies, although opportunities are site specific and seasonally dependent. Engines and turbines need further development to provide necessary performance guarantees. Long term demonstration of bio-oil in diesel engines and gas turbine has not been possible due to lack of large quantities bio-oil. There are similar advantages in storage and transport as for heat applications, although special combustion equipment and start-up and shut down procedures are likely to be needed.

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Transport Fuels Applications

For production of transport fuels there is current interest in gasification of bio-oil/charcoal slurry, which will soon be tested as fuel in a high-pressure gasification unit in Germany, with synthesis of hydrocarbons from the resultant syngas. Use of a bio-oil – char slurry maximises the overall conversion efficiency of the pyrolysis process to a transportable fluid, although solid char contents above around 10% may be difficult to handle. The advantage of this approach is the ease of transport and pressurised feeding of a liquid product. Bio-oil can thus be considered an energy carrier.

Chemicals Applications

The only current commercially viable opportunities are in the food flavouring and additives sector (e.g. liquid smoke), however this is a specialised market. Resins and adhesives for wood panels have been widely investigated with promising results for phenol substitution, but exploitation will require attention to product quality and consistency and defined quality standards. Another opportunity is in speciality fertilisers in which nitrogen is added to the pyrolysis process or the bio-oil product to give a slow release fertiliser. Hydrogen production from whole bio-oil or tar (from slow pyrolysis) is unlikely to be competitive, but the aqueous fraction from phenols recovery or the gas from charcoal production can be reformed to produce hydrogen. A number of speciality chemicals can be derived such as levoglucosan, anhydrosugars and sugars, none of which yet have a discernible market.

Research

It is hard to get funding from EU and national programmes for fundamental research. Fundamental research needs to be linked to applied research, but is essential for successful commercialisation by improving an understanding of the process leading to optimisation and by explaining variations in performance between feed materials, technologies and scales of operation.

Conclusions

Fast pyrolysis offers a flexible and attractive way of converting solid biomass into an easily stored and transported liquid, which can be successfully used for the production of heat, power and chemicals. Implementation of this technology is, however, hindered by several factors:

- Feedstocks need to be available at the lowest possible cost compatible with suitable physical and chemical characteristics.
- Initially feedstocks are likely to be wood and woody materials and major industrial waste materials with minimum ash and contamination such as bagasse,
- In the future, the feedstock base will include lower-cost biomass materials such as residues, wastes, mixed and contaminated materials,
- Biomass supply chains need to be developed and optimised both technically and economically, and conventional equipment, when possible, should be used to minimize the cost,

- Scale-up of pilot and demonstration plants is an important next step for the sector and support and encouragement is needed,
- There is very limited availability of sufficient quantities of bio-oil at a reasonable cost for long term testing as required to establish performance guarantees for boilers and engines,
- There is very limited availability of bio-oil for exploratory research,
- Support for process optimisation and supply of large quantities of bio-oil for testing should be provided through continued operation of existing pyrolysis plants,
- The continued emphasis on innovation for new processes reduces attention on necessary process development,
- Continued attention needs to be placed on developing bio-oil that is consistent and has improved basic physical properties such as lower viscosity, longer storage life and lower solids content,
- The compatibility of bio-oils from different processes and different feed materials needs to be investigated,
- Encouragement should be offered to explore new ways of using bio-oil for energy, fuels and chemicals,
- The development and publication of norms and standards and all relevant regulations for handling, storage and transport of bio-oil need to be addressed in a centralised and coherent way with widespread dissemination of recommendations and procedures,
- Active promotion of the opportunities offered by bio-oil with sensible and positive publicity is important for the successful implementation of fast pyrolysis in the market place,
- Networks are a very effective way of supporting development, identifying and prioritising issues, and directing future directions, particularly if they can be provided with financial, resources to address the most critical problem areas,
- Pyrolysis and gasification should be seen as complementary not competitive.

Recommendations

- Recognise that plentiful and regular supplies of bio-oil need to be made available for long term testing.
- Provide resources and support to ensure that adequate supplies of bio-oil are made available at a reasonable cost.
- Recognise and support fundamental research into production and application of bio-oil to provide support for industrial development.
- Encourage network activities as a very effective way of supporting development, identifying and prioritising issues and future directions; networks should continue to attract strong support including additional financial resources to address the most critical problem areas and analyse key topics.
- Fundamental research is vital to the successful optimisation and development of commercial processes and needs to be encouraged in its own right, either through traditional routes or via Networks.
- The strong emphasis on close collaboration between university and industry should be relaxed. Sometimes such co-operation is essential, but the short term commercial objectives of industry are not always compatible with the creativity and innovation associated with academia, and can lead to imaginative inventions and development being stifled.

- Pro-active promotion of fast pyrolysis and bio-oil as renewable energy sources will help overcome the sometimes negative image of the technology and the product.
- Education and training in this and related sectors is essential in order build up a core of knowledge and expertise on which a viable industrial sector can be built.

WASTE

Waste definition

The workshop thought that it is imperative to have a large definition of what is Waste as feedstock for the Pyrolysis and Gasification technologies. The reason is that the various terms like “Residues”, “Waste”, “Refuse” are used in literature and there is some confusion to both technical and non-technical people when publications appear.

Despite the fact that waste is defined legally by various countries and organizations, the confusion remains and the communication of the results becomes fuzzy. The definition given to Waste is as follows: A stream of materials is defined as a Waste within a specific context when it is a refuse without objective value; otherwise it constitutes a material at the end of its usefulness. The reason the definition includes the expression “within a specific context” is that spatio-temporarily the same material can have different value, both positive, negative or none depending on many parameters, whose analysis is beyond the scope of this work.

In the opinion of the Workshop the term “Waste” becomes more and more obsolete because of the relative value a waste stream can have within a specific situation. It is proposed to replace the term by the term “Residues” which has no the meaning of “non-usefulness”.

The technological challenges

There are two levels of technological challenges: the ones at the level of the pre-treatment technologies and those regarding directly Pyrolysis & Gasification.

Technical barriers for the commercialisation of Pyrolysis & Gasification

In what follows a list of technical barriers was proposed by this workshop; it includes all technical barriers it must be understood that some of them apply and some do not in a specific technology:

- Feeding modules depending on Waste stream
- Bed material handling (for FB gasifiers)
- Syngas clean-up (both cold and hot)
- Products characterization (Standards/Norms)
- Environmental Performances/Health and Safety
- Reliability/Troubleshooting
- Need to mature the technologies under development and develop new ones

Non-technical Barriers for the commercialisation of Pyrolysis & Gasification

- Feedstock availability (spatial and temporal): this factor is crucial to the techno-economic feasibility of the project. Projects in this field become economically sound above a marginal treatment capacity, which is usually quite high. If the feedstock is not available locally and must be found at places considerably remote from the application area the cost might become prohibitive.

- Project set-up (all steps): When a promoter set-up a project, there are numerous steps to get through and which are sometimes time consuming (i.e. financing, permitting). The funds available for this step are not inexhaustible and "run-out of money" is a usual situation.
- Bad information / Social acceptability: Environmental pressure groups are very efficient in transmitting and communicating their "buzzwords" to the society, thus creating the perception they defend. Sometimes these perceptions are not expressing the reality and this is the case for pyrolysis and gasification. A better vulgarization of the situation is necessary to change some bad perceptions constituting "show-stoppers".
- Permitting: different in each country but generally difficult and time consuming.
- Competition from other technologies (i.e. incineration): At the time being, incineration has a bad name. This can change in the future and incineration can become a very important competitor for pyrolysis and gasification.
- Environmental Legislation: It is or could become a positive or negative catalyst towards commercializing pyrolysis and gasification of waste streams.
- Energy Policy and other Political issues: Energy is the most important commodity in the World. Energy policies can also become positive or negative catalyst towards commercializing pyrolysis and gasification of waste streams.
- Market fluctuation: Perceptions and realities influence the course of the stock market and consequently the market at large.
- Financing of Demonstration Units: it is usually difficult for new technologies in this field to persuade financiers to invest on demonstration projects.
- Costs at all levels.

The social acceptability issue

The workshop considered that this issue is very important and spent some time in defining it and propose how to proceed during the steps of the project set-up. The consensus established during the Workshop is described below:

- Social acceptability is created around a set of conditions to be fulfilled in a given project and accepted by a large majority of the 'public opinion'. The meaning of majority meaning that, in case of lack of total consensus, is the large majority which defines the acceptability limits.
- For environmental projects, in which the issues are complex, the set of conditions is established via an 'informed consensus' among all 'actors' involved in the decision-making process.

Landfilling

Special thoughts were expressed during the Workshop on the relation between landfilling and the successful implementation of Pyrolysis & Gasification in the field of waste management.

It was clearly and consensually established that the eventual penetration of pyrolysis and gasification in waste management is a strong function of the landfill cost. As we know that this cost varies from country to country the possibility of success in implementing pyrolysis and gasification is a function of geography and socio-political decisions. It is also thought that governments, through appropriate legislation taking into account the externalities costs, will play a decisive role.

Conclusions and Strategies

The Workshop concludes the following:

- Waste is a very promising feedstock for pyrolysis and gasification
- There exist already commercial successes
- Because of the variety of the Waste more R, D, D and C work is needed
- The non-technical barriers are more influential than the technical ones
- Landfill costs is a crucial factor
- Energy and Environmental policies will play a very important role

The following strategies are proposed for a successful implementation of Pyrolysis & Gasification as valuable options within any Integrated Waste Management Project:

- See Pyrolysis & Gasification as the technologies of the future for Waste Valorization.
- Improve the technologies
- Inform people and government efficiently
- Explain that the Valorization is hierarchically at a higher level than landfill and impose restrictions allowing for Waste to have a higher negative tipping fee
- Face systematically and drastically all other non-technical barriers.

SYNGAS FOR SYNFUELS

Introduction

This discussion summarizes an experts workshop on biomass-derived syngas for synfuels applications conducted at the "Expert Meeting on Pyrolysis and Gasification of Biomass and Waste," Strasbourg, France, October 1, 2002.

Transportation fuel security and greenhouse gas emissions reduction are the most important drivers for the interest in biofuels. Synthetic fuels – derived from bio-syngas - can be produced from a broad range of biomass feedstocks. Examples are methanol, ethanol, hydrogen and Fischer-Tropsch (F-T) liquids. F-T liquids and ethanol can be relatively easily introduced into the existing transportation sector; whereas methanol and hydrogen for fuel cell vehicles are expected to offer a better lifetime economy, but require serious adaptations in fuel distribution infrastructure and automobile technology.

Several automobile manufacturers are interested in high quality synthetic biofuels, partly because synthetic fuels may have improved performance in newly developed engines, compared to traditional oil derived fuels; and also because they see F-T liquids from biomass as an early opportunity to meet society's (the customer's) demand for environmentally sound actions. Manufacturers' representatives are very interested in new developments.

Technology for the production of synthetic fuels from syngas is not new. Methanol and hydrogen are generally produced from natural gas, and there is experience with F-T liquids production from coal. Worldwide, some 85 installations produce chemicals from syngas, for example, methanol, ethanol, mixed alcohols and hydrocarbons. Parallels in fossil fuel technology show that all steps in biomass to synfuels processing, such as pre-treatment, gasification, gas cleaning, make-up, and synthesis are possible at significant scale, and, moreover, that the whole combination is possible as well.

Nevertheless, integrated concepts of synthetic biofuels have been demonstrated only in limited demonstrations, and large-scale developments are on hold. The central question in this workshop is therefore to identify the most important technological and non-technological barriers to implementation. This should also lead to recommendations for direction for governmental programs.

Technological Barriers

Required Gasifier

For successful large-scale production of synfuels a fungible–a commercially interchangeable commodity product–syngas is required, i.e. a clean gas mix of primarily H_2 and CO with the right composition. It was stated that large gasifiers are required to produce synthetic fuels at the lowest cost (economy of scale). The understanding of downstream requirements of the ultimate process gives direction to the development of large commercial gasifiers, gas cleaning and make-up processes. Some experts hold the view that for the ultimate large-scale processes, oxygen-fired pressurized gasification is a requirement sine qua non.

However, current gasification R&D is mainly aimed at decentralized CHP application, which is typically operated at atmospheric pressure and with air as gasification medium. This may mean that gasifiers for CHP are not suitable as demonstration for synthetic biofuels production, and that the development of the required gasification technologies for large-scale fuels production follows a different R&D path. For the eventual large processes, it is therefore suggested that gasification R&D should–from now on–only focus on large-scale syngas production, with the perspective to scale-up up to 500 – 1000 MW_{th} input.

For a demonstration plant, the gas composition from the gasifier is not the central aspect, as a shift reactor (with or without CO_2 removal) can make every gas suitable for methanol or F-T production.

Gas Cleaning

Downstream processing requirements can be subdivided into gas cleaning (contaminant specifications) and gas conditioning (process conditions). The latter concerns primarily the H_2/CO ratio–which can be met through the water gas shift reaction–and the concentration of inerts (N_2 and CO_2). The major technological barrier in converting bio-syngas into synfuels may thus be in gas cleaning. Some experts suggested that the biomass research community should focus on producing a clean bio syngas and leave the connection to biofuels (i.e. gas conditioning and fuel synthesis) to the “synthesis guys”.

Requirements for gas cleaning are mainly dictated by the application, and furthermore by the amount and character of the contaminants as a result of feedstock used and gasification technology applied. Catalysts used in the production of methanol and Fischer-Tropsch liquids are easily poisoned by small amounts of alkali metals, halides, and sulphur compounds, which therefore need to be removed to ppm or even ppb level. These levels are much stricter than levels for electricity and heat production, for which most gasifiers are developed at present. There is obviously a break-even point between costs for severe cleaning and costs due to loss of catalyst activity. With ongoing development the acceptance levels for catalyst poisons may go up, or catalysts may become cheaper, and cleaning methods may improve quickly.

Discussion on this topic also revealed an area of conflict between commercial catalyst development and scientific interests. The scientific world complains that much is unclear concerning the requirements of new catalysts, as catalyst manufacturers consider new catalysts proprietary and do not disclose catalyst formulation or poison tolerance details to the public. For example, although the F-T process has been known for 80 years, it is difficult to buy a suitable catalyst.

It is also suggested that one should opt for newly developed gasification processes that produce a cleaner gas to start with. If the economics and scale-up ability of these processes are good, they deserve serious attention. Others share the opinion that the present status of gas cleaning can already fulfil requirements for a demonstration plant. Demonstration will automatically lead to further improvement.

Non-Technical Barriers

Diversification or Focus?

With the amount of biomass that could be grown in the European Union, a maximum of 20 % of the transportation fuels needed could be produced. Part of the audience prefers that governments make a decision on bio-energy applications today. For instance, some experts feel that decision is needed to use biomass either for CHP or for transportation fuels, and within the transportation fuels area whether the industry should focus on a limited number of fuels, or look at the whole range of fuels. An official focus has the advantage that a clear sign is given to all scientists and developers about the eventual aim of development; and, therefore, that research funding is more effectively spent on the most promising options. Others find that the broad range of applications should remain open, so that the most advantageous option will eventually emerge in the biofuels market.

Although numerous studies have compared the relative economics of biofuels throughout the years, there is no consensus on which biofuel to concentrate developments. Various biofuels from extraction, esterification and hydrolysis-fermentation are named as important alternatives. However, in the long term the preferred process uses the complete energy crop, which may favor a route via the syngas platform. The high temperatures used in gasification processes pose a limit to the maximum efficiency. It may be advantageous to combine a very efficient low temperature process for fuel production from part of the biomass, after which the residue is still suitable for gasification and electricity production.

There are also practical reasons to focus on a particular class of fuels. From an oil company perspective F-T is considered attractive, as it allows the use of existing infrastructure for further processing and distribution. For the long-term, hydrogen from syngas is envisioned, but that route will prove difficult to extend to broad application because of the time and costs associated with infrastructure development. To realize biofuels market penetration within a 10-year timeframe, the industry may need to focus on fuels that are the easiest to produce, even though they may neither be the most economically attractive in the long term, nor be the best options for greenhouse gas emission reductions.

The discussion on whether to focus on one fuel, or to keep all options open, cannot be decided in the experts meeting, but needs to be continued at a higher level.

Company involvement

There is some worry by oil companies' representatives about introducing a green fuel component into their product mix. In some countries, the cooperation between research institutes and major oil companies is not obvious. While some companies seem to be reluctant, others are starting to become interested in alternative fuels, or already have committed themselves to research in this field. This also shows from the representation of several oil companies in this workshop.

The major objections from the oil companies concern the long-term guarantees for attractive economic conditions to sell the fuel produced. For companies to participate they need profitable and stable long-term market conditions; this needs to be created by the European governments. Furthermore, the technology is not yet ready for large-scale application.

The fact, that a lot of natural gas based synfuel projects are under active development, represents an opportunity to get synfuel related research done, which could then also be applied to biomass at some stage in the future.

Feedstock Supply

The supply of inexpensive feedstock is a major barrier for large-scale bioenergy application in Europe. For both the cultivation within Europe, and the import from outside Europe, government support and long term guarantees on tax exemption and regulations are needed. Waste is seen as a very big, almost inexhaustible feedstock. The import of biomass already happens for other applications, and parallels to fossil fuel (coal) transport hint the practical and economic feasibility.

Competition on Two Fronts

In both the feedstock and product arenas, bio-energy operates in competition with other applications and products. Cultivation of bio-energy feedstock competes with the growth of food crops, and, to a lesser extent, with material crops. In Europe, the influence of agricultural policies on the success of bio-energy growth will be huge.

On the product side, there is obvious competition with products from oil and natural gas. Biomass-derived H_2 is more expensive than H_2 from natural gas. Fischer-Tropsch liquids costs are too high, so that production only becomes feasible at very large scales, i.e. 1000 MW_{th}. The consensus is that biofuels cannot be produced cheaper than their fossil alternatives within the next 15-20 years. Long-term incentives are needed in the form of tax regulations. The benefits of bio-energy should be taken into account, and be given a monetary value.

Instructive parallels are seen in Brazil and the USA, where large amounts of biomass are already used for energy applications. There, both the large production scale and partial application for other applications decreases the costs.

Bioenergy demonstration projects only cost money. Governments need to pay for not only R&D, but also operation of at least midsize demonstration plants. One of the most difficult challenges facing government and industry is how to manage the transition from government-subsidized R&D to industry-led commercialization. Much technical development fails because of the inability to make this transition. The general opinion is that governments and the public should not expect the demonstration plants to produce synthetic biofuels at a price competitive with fossil fuels.

Conclusions

The production of biofuels from bio syngas is technically feasible. Many coal-to-chemicals processes show that the integration of gasification, cleaning, make-up and catalysis is possible. What is needed now is the development of similar large-scale biomass based processes.
Some experts feel that gasifier RD&D should focus on large-scale syngas production, using oxygen blown pressurized gasifiers, which have the perspective to scale-up to 500–1000 MW_{th} input. For synthesis of biofuels, a fungible syngas (a commercially interchangeable commodity gas, a clean mix of primarily H_2 and CO with the right composition) is a prerequisite.

There is some disagreement on the gas-cleaning subject. Gas cleaning requirements for synfuel production are very strict; some share the opinion that gas cleaning remains therefore the major barrier in synfuels production, but new voices state that it has been demonstrated that these specifications can be met (for coal, waste, as well as biomass feeds), and that research efforts should be concentrated on gasification research instead.

Non-technical barriers focus on the system economics (plant size, technical risks, dependence on government support), the feedstock availability, costs and infrastructure. It should be realized that small-scale demonstration plants will never produce biofuel at competitive costs. These projects need not only governmental support for RD&D, but for their complete lifetime. Also, large-scale biofuels production facilities will not be economically competitive with fossil based plants if their environmental advantages are not valued, or if the market situation does not change. Society demands that oil companies produce biofuels, but the extent of oil company involvement in research and development depends on the long-term prospects of the biofuels market.

The decision to either focus on a few biofuels or keep all options open is left for later discussion in broader platforms. There was no agreement on which biofuel is the preferred in the short or long term.

For large-scale biomass feedstock supply, parallels are seen in the USA and Latin America where cheap biomass is available. Bioenergy cultivation in Europe can be enhanced through stimulation of multipurpose products, agricultural policies, and by creating a biomass demanding market.

The European government now needs to make a clear decision for stimulating commercial biofuels application–a decision that includes both tax regulations and long term guarantees for green products, and investing in RD&D in order to improve chances for biofuels production.

POWER PRODUCTION BY ENGINES, TURBINES AND FUEL CELLS

Background

This report provides a summary of issues discussed at the Power Production workshop of the expert meeting on Pyrolysis and Gasification of Biomass and Waste, held in Strasbourg on 1 October 2002. The objective of the workshop was to identify the technical and non-technical barriers associated with power production in conjunction with pyrolysis and gasification of biomass and waste. Where appropriate, suggestions made by delegates of possible solutions or requirements for further research in order to overcome these barriers have been included.

Introduction

The workshop focused on methods of producing electricity from syngas, pyrolysis oil or char produced by waste or biomass pyrolysis or gasification technologies. Issues related to receipt and handling of the derived fuels were not discussed, but those relating to fuel delivery to the prime mover, fuel combustion or electrochemical decomposition and supply of electricity to the market were included. Barriers identified were divided as either technical or non-technical.

Technical barriers were considered in four categories – those related to the use of:

- Boilers (for power generation via a conventional steam cycle)
- Reciprocating engines
- Gas turbines
- Fuel Cells

Non-technical barriers are, in many cases, not related to specific technologies and so have been considered generally for all the above power production systems.

Technical barriers

Boilers

There are technical challenges associated with the combustion of syngas, char or pyrolysis oil in a boiler to raise steam that can then be used in a conventional steam cycle to produce electricity. Three major areas were identified to which attention must be paid:

- The need to achieve good combustion - which requires, for example, appropriate design of burners and fuel atomisation systems. This is particularly important for pyrolysis oil. However, these barriers are surmountable with appropriate design engineering and examples of operational plants show that appropriate systems can be achieved.
- Potential for fouling – The presence of certain compounds in the biomass or waste derived materials (particularly alkali metal compounds) results in a potential for fouling of boilers. The effects of this can be minimised by appropriate boiler design (tube spacing and configuration, temperature ranges etc), inclusion of appropriate diagnostic instrumentation for online condition monitoring and, if necessary, implementing an appropriate cleaning regime. These are established techniques, which can be included as design precautions for particular applications and do not represent a fundamental barrier to project implementation.
- Potential for corrosion – The presence of certain chemical components in the original feedstocks (particularly halides in waste) may give rise to potential for corrosion during

combustion. This can be minimised by maintaining appropriate temperatures and combustion conditions and is therefore not a substantial barrier.

All of the above barriers have known solutions, which require appropriate design and application. For example there has been development work on burners for boilers using wood-based pyrolysis oils by Oilon (Lahti, Finland) in co-operation with Fortum (Porvoo, Finland).

However, the largest barrier for this method of power production is that it does not achieve a very high efficiency. There are thermodynamic limitations on steam-cycle efficiency, but in addition the problem is exacerbated for these plants by the following:

- It may be necessary to impose low steam conditions to prevent corrosion and other problems
- Temperatures achieved in combustion of these fuels may not be appropriate for high efficiency cycles
- The catchment area of biomass and waste plants is limited by logistics and economics, which limits plant size, necessitating the use of smaller steam turbines, which tend to be less efficient
- This logistics/size issue does not permit the economies of scale, which would make the use of higher steam conditions (giving higher efficiencies) attractive.

The latter two barriers are not strictly technical and, while no-one present had heard of biomass or waste plants operating at ultra super critical steam conditions, there were reports of a 6 MWe plant which operated at 66 bar, 550 °C. Regarding low combustion temperatures there were reports of plants co-firing natural gas or using gas-fired superheaters after the boiler to overcome this problem.

Reciprocating engines

There is considerable experience combusting syngas in reciprocating engines and more limited experience of using pyrolysis oil. The engines have to be adapted individually, looking at the particular fuel involved, but the technical feasibility of doing so is proven. Despite this there is not sufficient long term operating experience (30,000 – 40,000 h) to give full confidence in the long term viability and costs of this method of power production. Some long demonstration work (of commissioning and long term operation) is essential to build commercial confidence.

The biggest technical barrier identified for reciprocating emissions was environmental emissions. NOx emission limits of the TA-Luft standards can be met with low-heating value biofuels are used, although more stringent standards could be difficult to achieve. However, CO levels tend to be higher than many legislative limits, particularly if low speed diesel engines are used.

The main options available for reducing CO are flue gas treatment technologies: catalytic or post combustion. Catalysts are able to reduce CO emissions, but they are sensitive to flue gas composition and poisons in the gas, so that performance can deteriorate rapidly with time. Also CO-emissions of a gas engine are lower at a high H_2-content in the gas than at a low H_2-content. One way around this would be to carry out a water-gas shift reaction to change the $CO:H_2$ ratio, but this would be very expensive. The alternative to use of a catalyst to reduce CO emissions is post combustion of CO, of which there is no substantial experience with pyrolysis gas,. but it is already well tested at landfill gas.

There is considerable uncertainty related to the costs of these post combustion units, preventing meaningful financial analysis of overall system economics. For engines adapted to run on landfill gases, the gas treatment accounts for 10-15 % of the complete turn-key engine package cost, with negligible additional operational costs on units which have run for up to 60,000 hours. Verification of the levels of these costs for other fuels is required.

A secondary issue is the presence of tars and condensate in syngas. The associated problems are surmountable by avoiding temperatures near the fuel dew-point, but this results in increased investment costs and it is important to have a reliable fuel analysis to achieve this, which may not be easy with waste and biomass feedstocks.

The use of pyrolysis oil in reciprocating engines presents considerably more challenges than syngas, partly due to the more limited experience. Wartsila have run trials on a 1.5 MWe engine fed with pyrolysis oil, but the work was then stopped for various reasons. Ormrod (UK) used a pilot injection of diesel oil to ignite pyrolysis oil in a six cylinder 250 kW engine (three cylinders fed with pyrolysis oil) and work on emulsions of pyrolysis oils and diesel oil has been performed by other groups in Canada and Europe. This experience base and the pyrolysis oil properties identify the following barriers and potential barriers:

- Polymerisation of fuel components in the injection nozzles
- Modifications required to the injection system to cope with the low LHV fuel (one method of addressing this is to use a pre-mix emulsion)
- Corrosion of the injection system (caused by pH of the oil and the presence of char particles)
- Particulate emissions
- Solids in the fuel (which can cause metal erosion)
- Alkalis in the fuel (which can cause fouling and deposition and are mostly contained within the char particles)

Several of the technical barriers are related to the presence of impurities in the fuel. It is possible to engineer a fuel injection system (for example) that is more compatible with pyrolysis oil than the standard systems (e.g. fuel delivery and injection systems should be as simple as possible to prevent blockages and materials can be chosen which are appropriate to the pH of the pyrolysis oil), but in the longer term it may make more sense to concentrate on upgrading the pyrolysis oil to make the biofuel more compatible with the currently available technology, as far as possible.

Oil filtration is an available technique, which will reduce char content and thereby also significantly reduce alkali content. Further work is needed on pyrolysis oil filtration to demonstrate its effectiveness in combating some of the above problems. Also, in order to better understand what is going on during combustion of the fuel (and hence appreciate the real reasons for some of the problems reported during trials) improved characterisation of the pyrolysis oil is needed. This work is progressing under the Altener programme.

Finally it should be noted that in some cases demonstration of combustion of pyrolysis oil in reciprocating engines has been difficult owing to a lack of available pyrolysis oil.

Gas turbines

The main attraction of using gas turbines to convert the energy in biofuel to electricity is the potentially high cycle efficiency. The average efficiency of biofuel-based gas turbine combined cycles can reach 45 % in case of pressurised gasification and 40 % for atmospheric gasification. This includes the slight increase in efficiency obtained because of the increased mass flow in the turbine when utilising low heating value biofuels. By comparison, the typical efficiency of gas engines are around 38-43 % in case of natural gas (depending on engine size). Using biofuels, if the H_2 content is relatively high and the plant quite large in size, 40 % can be attained, while 35 % is a typical average value for smaller capacity systems.

The choice between gas engines and gas turbines is mainly a matter of size (turbines are more appropriate for larger size plants, gas engines for smaller ones). However, the nature of biomass again constrains larger developments, so that 35-40 MWe would be a reasonable sized gas turbine based plant, which could benefit from the efficiency advantages of increased scale, without suffering the economic disadvantages of increasing the biomass catchment area to supply fuel demands. While micro-turbines offer promisingly high efficiency cycles at smaller scales there is limited experience with the use of biofuels in micro-turbines.

Lean-premix combustion technologies have been developed to control CO emissions and low dioxin levels can be simultaneously obtained e.g. in Varnamo, 50 % RDF and 50 % wood fuel gave dioxin emission levels of 0.01 ng/Nm^3 (comfortably complying with the Waste Incineration Directive limit of 0.1 ng/Nm^3 for dioxins). Thermal NOx is also reduced by the lean-premix technologies. However fuel NOx is a much more significant technical barrier. The efficiency of biomass combined cycle systems could be improved by having a higher inlet temperature to the gas turbine and using hot gas cleaning (although there are limiting factors related to mechanical considerations on materials and component lifetimes) However, if hot gas cleaning is implemented to avail of the related higher cycle efficiency it is difficult to remove ammonia from the syngas and this will form NOx upon combustion in the gas turbine, likely giving rise to NOx levels which exceed current legislative limits. This is a major problem that requires to be addressed.

There are also technical issues that need to be taken account of in the design of the heat exchanger/gas-cooler for gas turbine exhaust gases. However, these can be addressed with available techniques and appropriate design engineering.

Pyrolysis oil presents more technical barriers than syngas. Many of these are similar to those listed in section 3.2 and the major ones include the following:

- Particles in pyrolysis oil causing erosion
- High alkali content in pyrolysis oil causing deposition
- Possible problems in fuel atomisation

The only significant practical experience of pyrolysis oils and gas turbines of which workshop delegates were aware is the work that Orenda in Canada has done, which includes gas turbine combustion trials on a 2.5 MWe machine, but not actual gas turbine operation. The published results suggest that deposition on turbine blades does occur and particles in the fuel do cause erosion, but appropriate maintenance schedules may be devisable to keep these under control. This needs further investigation/confirmation, paying particular attention to the actual quality of pyrolysis oil used, specification of maintenance intervention required, feasibility of this and development to actual operation in a gas turbine.

It is likely that further investigation of this area would result in recommendations relating to limits for solid/ash/alkali metal levels in pyrolysis oil for use in gas turbines. The challenge of meeting this would require upgrading of the oil and research and development should be focused in this area.

Fuel cells

Fuel cells offer the potential for very high power generation cycle efficiencies with low levels of emissions, but they are not yet readily commercially available and there is little experience of their operation with biofuel systems. Of the four fuel cell categories those of most interest for biofuel power generation are the molten carbonate and Solid Oxide Fuel Cells.

The technical barriers specific to biofuel systems are likely to be purification and conditioning of the syngas. While pyrolysis oil, like many other hydrocarbons, could potentially be steam-reformed to produce a gas for use in a fuel cell, it is not considered likely that it would be attractive to directly use pyrolysis oil for power generation in a fuel cell system.

The major obstacle to deployment of fuel cells in biomass and other systems is the lack of commercially available molten carbonate or solid oxide fuel cells. It is anticipated that, even if these were commercially available, the cost of the system would continue to be a barrier in the near future.

Other technical barriers envisaged include onerous gas purity requirements, variability in gas composition from biomass sources and potentially operation and maintenance requirements/costs. The first technical barrier to be overcome is actual demonstration of a fuel cell system operating with biogas – then we will find out what the other technical barriers are. It was suggested that biogas could be combined with other gases in early demonstration work and possibly in final applications to limit some potential problems.

Some delegates observed that studying the whole cycle from gasification to electric energy generation, the final overall efficiency of the system could be not much better than the more conventional systems discussed above (owing partly to requirements for conditioning of biomass syngas). This would limit the attractiveness of fuel cells for biofuel systems. However, advances in gasification technology (as gasification in supercritical water, producing 75 % H_2 rich gas, which is still in its early – but very promising – stage of development in Netherlands and Germany) could modify this.

Non-Technical Barriers

The primary non technical barriers identified by delegates are outlined below.

Environmental costs

The single most important issue facing pyrolysis and gasification of biomass and waste is the economics of power production from these technologies. They are not cost competitive with conventional methods of power production except in certain niche markets. Their advantage is their lower level of environmental emissions, especially CO2 emissions. Until this is recognised by fiscal policies which allow the actual environmental cost of power production by different technologies to be subject to commercial market forces these technologies will remain, by and large, uneconomically attractive.

Availability of the feedstock.

Moreover, feedstock market conditions can change, as costs are determined by competition with already well established markets. This is the case of Northern Europe, for instance, where wood by-products have a long history and problems exist in creating new markets

Cost of electricity and cost of fossil fuels by comparison

These are so low in many countries as to make most forms of biomass based generation expensive by comparison. As stated above, unless the environmental benefits of biomass systems are recognised financially there cannot be a level playing field with fossil-fuel based technology.

Guarantees

Many of those involved in technology development at the workshop expressed frustration and concern at the guarantees that are expected from them as a technology provider, with insufficient regard to how other factors beyond their control (e.g. feedstock characteristics) may be influencing performance.

Image

Technology developers also identified the fact that when installing systems, customers tended to want a reduction in capital costs. This would often be achieved by cutting technical corners and the result was a plant that did not perform optimally and therefore did not provide a good base from which to promote or develop the technology.

Timescale

Time required for the implementation of bio-energy projects

Economy of scale

The logistics of harvesting and transporting biomass supplies means that plant sizes tend to be small and do not benefit from commercial economies of scale available to competing technologies.

Cogeneration

Biomass systems can be more commercially competitive in a combined heat and power configuration, but requirements to site plants near fuel sources makes the use of heat more difficult than for some competing technologies. District heating is a large potential market for biomass fired plants in many parts of Europe, but it is difficult for new biomass technologies to break into the market when there is already a heat supplier to the system.

Operation and maintenance

For pyrolysis and gasification plants attention needs to be paid to establishing an operational skills base. While it is not unduly difficult to obtain personnel experienced in power generation and control, it is much more difficult to find operators who also have the right balance of chemical engineering skills and specialist knowledge for these plants.

Electricity market

In some countries the electricity market trading mechanisms do not encourage small scale generators, including those using pyrolysis and gasification of biomass and waste. For example in the UK, the risk of penalties under NETA for failure to generate after declaring capacity can be onerous. Similar situations exist in other countries.

Public perception/lack of understanding

This was identified as an obstacle for the advanced technologies, particularly with regard to obtaining necessary permits and licences, even within the relevant authorities.

Financial incentives

Non-uniformity in EU legislation on bio-energy tariffs and incentives is also a reason for unbalanced development of bio-energy across Europe.

ECONOMICS

At the beginning of the workshop the participants defined the topics of common interest. Five topics were selected and discussed during the workshop. The results are summarized below.

Promotional database

The participants felt that there are already success stories but not well documented. The Güssing case was discussed in detail and stated that it is not only a technical but also an economical success especially due to the benefit of the whole region (wood farmers, job creation, etc.).

The pay back time for bio-energy plants is important for investors. The participants especially from industry agreed that the necessary pay back times are:

15 years	for power plants
3-5 years	for pulp and paper industry
even smaller	for risky projects

As a result of this discussion a promotional database was demanded. This database shall include technical as well as economical data and also data from the region where the plant is located. This database could promote potential investors to invest money into bio-energy projects.

Availability of waste fuels

Due to European and national legislation and improved collecting processes more and more waste fuel are available as fuels at a low prize. Therefore, opportunities exist for operators of bio-energy plants to use such low prize fuels to improve the economy of their plant. But most technologies are not ready yet for such low quality fuels.

As a result of this discussion it was concluded that more attention has to be paid to low quality fuels from waste streams during the development of bio-energy plants in order to be able to use these opportunities and to improve the economics of the plant.

Funding/support

It was agreed that funding and support is necessary for the implementation of bioenergy plants. The question was raised which kind of support it should be.

The majority of the participants shared the opinion that internalising the external costs would give “real costs” and this would be a strong support for bio-energy.

There was a broad discussion about taxation versus “green credits”. It was agreed that taxation is the preferable instrument.

Financial funding for bio-energy technologies is limited. Therefore, it was proposed by some participants to only select promising technologies for funding. But no better procedure could be found during discussion for the selection of the promising technologies than that already performed for example by the European Commission. However, some elements could be improved such as the selection of experts.

Biomass industries

A successful biomass industry already exists in the bio-ethanol production in Brazil and US and both cases were examined intensively during discussion. For both cases it was seen that the political intention and demand is the most important driving force for this successful implementation.

True numbers for assessment

Two diagrams showing “specific green house gas emissions” on the one hand and “energy pay back” on the other for different renewable energies were presented at the workshop. The participants did not believe the numbers shown in the diagrams and it was evident that these figures are only used to influence the public in a certain direction i.e. lobbying.

It was generally agreed and strongly demanded that the bio-energy society has to use and evaluate “true numbers” very urgently for assessment of renewable energy.

CONCLUSIONS AND RECOMMENDATIONS

Each of the six topics selected by the delegates to the Expert Meeting has been reviewed above with a large number of topic specific and more general conclusions and recommendations. Common themes are selected for inclusion in these overall conclusions and recommendations to emphasis the most important points that should be addressed strategically.

Incentives

Incentives are essential in the short term to provide sufficient commercial interest to justify investment. These incentives need to be both of sufficient significance and of sufficient duration to provide enough encouragement for companies to invest and operate the plant.

There are examples of successful renewable energy industries in the USA and Brazil and both have benefited from major political and financial commitments that reassure the industries concerned that the opportunities are commercially attractive.

Qualitative and political encouragement through procedures such as life cycle assessment and environmental impact assessment, are not sufficient by themselves to have any impact on commercial decision making and economic evaluation.

Feed materials

Biomass and wastes need to be priced at a sufficiently low cost (with direct or indirect incentives) that heat and power products from conversion can be sold competitively. Alternatively the product values can be enhanced through direct or indirect incentives. The feed cost is often the largest single cost component and its minimisation is therefore key to reducing renewable energy costs.

While wastes are often viewed as having a negative cost from avoidance of disposal, there will always be some feed preparation requirement which will have an associated cost and if the waste fed process is seen to be financially attractive there will be pressure from the waste generators or suppliers to reduce the disposal credit.

Feed preparation for advanced thermal conversion is therefore an area that deserves attention and support.

Investment

There are many sources of funds to support the development of a new process to pilot or demonstration scale. However, until the process has proved itself over many thousands of hours operation, commercialisation is not possible, but the cost of achieving this extent of operation can often inhibit exploitation so that many promising developments are abandoned. Support should therefore be made available for more routine operation of existing plants to demonstrate the feasibility, viability and reliability of the technology.

Such operations should be coupled to both a public awareness and promotion campaign as described below and also provision of education and training opportunities to maximise the benefits of such support. In the case of pyrolysis, this would also provide substantial quantities of much needed bio-oil for extended testing in applications.

Finance

Many initiatives in advanced thermal conversion are undertaken by small to very small companies who have limited financial resources to carry out development and support the subsequent commercialisation and implementation, particularly in providing performance guarantees that are essential in most situations. Consideration should be given to providing financial resources such as guaranteed venture capital or guaranteed performance levels to support such ventures.

Innovation

As technologies mature, the potential and need for innovation moves from concept to detail. This requires investment in process development rather than process inn ovation, and while less exciting, is an essential stage in the development of a new technology if it is to be successful. The importance of this stage cannot be over-emphasised and requires support to bridge the funding gap between construction of a pilot or demonstration unit and the first commercial sale to provide for optimisation and proof of performance needed for performance guarantees.

Fundamental research and Co-operation between industry and academia

New technologies are mostly derived from initiatives taken many years previously in research laboratories in universities, institutes and companies. Fundamental and blue sky research is important for the new technologies that evolve and for deriving an understanding of the basic science and mechanisms that enable processes and systems to be optimised. While there are clear benefits in encouraging and promoting cooperation between the researchers and companies involved in implementing the resultant technologies, both groups have fundamentally different objectives and provisions should be made to encouragement their contributions both separately and jointly.

Public perception / lack of understanding

The reaction to public and scientific concerns over the environment and greenhouse effects has been the promotion and support of a range of renewable energies. These are widely recognised as important and necessary, but only as long as they are sited well away from habitation. This contradiction has to be addressed through a more coherent and positive public relations exercise both generally and specific to projects, and appropriate encouragement and support should be provided.

An example of the problems that can be created is the new European IPPC legislation controlling the operation of gasification and pyrolysis plants which places such an onerous technical and financial burden on technology developers and implementers as to severely limit the rate and penetration of the technologies.

The EC Campaign for Take-off was a timely exercise but which has not had such a wide or extensive impact as planned. Publicity support such as this would help to overcome the inhibitions and negativity often associated with renewable energy. Professionally produced video and static publicity should be supported with the widest possible dissemination.