Biomass pre-treatment for bioenergy

Policy report

The Thunder Bay power station of Ontario Power Generation where steam exploded pellets are burned.

IEA Bioenergy

InterTask project on Fuel pretreatment of biomass residues in the supply chain for thermal conversion

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Abstract

An increased demand for biomass means that greater mobilisation of biomass resources will be required to meet demand. The availability of biomass has been addressed in many studies and may be limited by various environmental, economic, logistical, technical or policy factors. Particularly in cases where the availability of a certain biomass type is limited by technical, economic or logistical factors, pretreatment technologies may be required.

This report summarizes the conclusions of an IEA Bioenergy Inter-Task project on *Fuel pretreatment of biomass residues in the supply chain for thermal conversion*. The report shows how currently available pretreatment technologies and technologies under development can potentially help in improving and enabling the supply chains for available solid biomass resources for thermochemical conversion. Five carefully selected case studies describe key options for pretreatment of solid biomass resources for energy generation, including their costs, effectiveness and commercial status. Case studies included biomass torrefaction, pretreatment practices of forest residues, treatment of municipal solid waste (MSW) to Solid Recovered Fuel for gasification, steam explosion of biomass, and leaching of herbaceous biomass.

General conclusions:

- It is important to diversify the resource base for bioenergy to lower grades of biomass, reducing logistic costs and increasing the fuel flexibility of various conversion technologies. Biomass pretreatment technologies that enable the production of a fuel with better defined specifications and increased energy densities can be instrumental in boosting the bioeconomy as a whole.
- Biomass pre-treatment steps such as washing, drying, sieving, leaching or thermal pre-treatment may significantly improve characteristics of lower grade biomass and therefore provide an attractive approach for enabling the use of such residues, which may broaden the resource base.
- Logistical challenges and high transportation costs involved when using bulky biomass can be reduced through biomass pretreatment producing a fuel or energy carrier with increased volumetric energy density.
- Several pretreatment technologies have the objective to convert a biomass into a fuel that has technical specifications closer to that of the original fossil fuel, hence reducing the need for new infrastructures and lowering the impact on plant performance. This becomes attractive if the cost savings in plant modification at the end user are higher than the additional costs of pretreatment.

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1 Introduction

Bioenergy technologies are exposed to changing boundary conditions. While society is moving towards a bioeconomy with closed loops for carbon and nutrients, the demand and price for biomass increases. In a fully developed bioeconomy, biobased materials will be recycled where possible, or cascaded, with efficient use of residues, with closed loops for nutrients as a minimum. This requires thorough considerations as to how to effectively and sustainably harvest, transport and use different grades of biomass streams in today's bioenergy assets, while at the same time securing long term availability, competitiveness, nutrient management.

As a result, it becomes more relevant to explore opportunities for diversifying the resource base to lower grades of biomass, reducing logistic costs and increasing the fuel flexibility of various conversion technologies. Biomass pretreatment technologies that enable the production of a fuel with better defined specifications and increased energy densities can thus be instrumental in boosting the bioeconomy as a whole.

This underlying policy report is one of the results of a Strategic Intertask Project that was initiated as a collaborative effort between experts involved in various Tasks[1] of the IEA Bioenergy TCP during the period 2016-2018. The project was initiated to provide insight to market actors and policy makers how (advanced) pretreatment can be instrumental in making existing biomass fuel supply chains more cost effective and fuel flexible. In order to achieve this objective, the project generated five practical case study reports for a range of pretreatment technologies, as well as a technology database module and the underlying policy report.

This report provides a brief summary of the lessons learned from the case studies and identifies a non-exhaustive number of key pretreatment technologies that could significantly help in enabling a broader and more affordable resource base for bioenergy.

[1] This project had involvement of experts from Task 32 (Biomass combustion), Task 33 (Gasification), Task 36 (Energy recovery from Waste), Task 40 (Biomass markets and trade) and Task 43 (Biomass feedstocks)

2 The rationale for biomass pretreatment

There is an enormous diversity in the physical and chemical characteristics of the biomass resources that are in principle available for bioenergy. These characteristics have direct consequences for the ability to use a certain type of biomass for a certain application. For the end user, clean woody biomass with a high quality (relatively low amounts of moisture and ash) has historically been favoured over variable lower grade fuels that may have relatively high nitrogen or ash fractions, low ash melting temperatures, high moisture content, excessive particle size or contain unwanted components such as heavy metals as such fuel characteristics may pose operational problems in feeding or converting the biomass to a final energy carrier. Yet, fuel pre-treatment steps such as washing, drying, sieving, leaching or thermal pre-treatment may significantly improve these characteristics and therefore provide an attractive approach for enabling the use of such residues, which may broaden the resource base.

Another reason for biomass pretreatment may be that there may be significant logistical challenges and high transportation costs involved when using bulky biomass residues, and improving the energy density by producing a fuel with increased volumetric energy density. This may enable the utilisation of (stranded) assets, that are far away from resources. A good example is the production of wood pellets, which has enabled tremendous growth in long distance shipping of woody biomass, allowing power companies in Europe, Japan and Korea to use wood residues from North America, Southeast Asia, the Baltic States and Southern Europe.

Pretreatment technologies can be placed in the supply chain in various locations, and impact the downstream supply chain in various ways in terms of costs or fuel quality. Some pretreatment technologies may have multiple benefits. For example, recent research findings indicate that torrefied fuels are not only better in terms of energy density and storability than raw biomass, but also significantly improve the corrosion behaviour through a reduction of Cl concentrations up to 90%. This can lead to significant costs reduction for adapted furnace and boiler designs. In case of flash pyrolysis however, torrefaction may be counterproductive as it may have a negative consequence on product yield. Careful selection of suitable pretreatment technologies is therefore crucial to optimise and diversify supply chains.

Pretreatment technologies can thus be defined as all intermediate process steps, through which physical or chemical characteristics of a biomass resource are modified on purpose, before it is used for final conversion into a useful energy carrier (heat, electricity, solid, liquid or gaseous biofuel).

2.1 DIVERSIFYING AND ENLARGING THE RESOURCE BASE

There are various estimates in literature on the availability of biomass resources depending on scope, time frame and assumptions for technical, economical or environmental factors that limit their use. By far most of the biomass that grows on the planet is not harvested at all, or used for other purposes (food, feed, material). Large amounts of biomass grow that could potentially be sustainably used for energy production with no negative socio- economic and environmental impacts. A summary of the estimated biomass resources available for energy in 2050 taken from the Global Energy Assessment [1] is shown in Table 1.

Table 1 Technical potential of biomass resources available for energy in 2050 [1]

Resource	Range (EJ)	Comment
Dedicated bioenergy crops	44-133	High uncertainty, depends on yields, diets, technology, and climate change
Crop residues	49	Soil conservation issues need to be addressed; GHG balance might depend on soil carbon balance
Manure	39	Relatively small uncertainty and few, if any, environmental issues
MSW	11	Relatively small uncertainty and few environmental issues
Forestry residues	19-35	Competition for other uses may reduce availability of residues
Total, excl. aquatic biomass	162-267	

The table shows that there is particularly a large uncertainty in the amount of dedicated bioenergy crops available, as this mainly depends on developments in future crop yields, food diets etc. Some other publications anticipate much larger potentials for bioenergy crops. More certainty exists around the availability of biomass types that become available from other processes, such as crop residues, manure, MSW and (to a somewhat lower degree) forestry residues.

Biomass may become available as a result of forestry or agricultural operations in the field (primary residues), from process operations (secondary residues) or as post-consumer waste (tertiary residues. Today, wood based biomass is the most commonly known type of biomass used. For many types of biomass, the secondary and tertiary residues can up to be 3-5 times larger than the primary residues [1].

2.2 REPLACING FOSSIL ENERGY CARRIERS

There is a large potential for various solid biomass fuels to substitute fossil fuels (coal, oil, natural gas) in different sectors of society. Coal is currently mostly used for power generation (in pulverised coal fired power stations) and in manufacturing industry (steel, cement, etc.). Oil is mostly used for the production of transportation fuels and to a smaller degree in non-energy uses (e.g. plastics). Natural gas is largely used for power generation, but direct combustion for provision of heat in buildings and industry are also important end uses of natural gas.

One of the scenarios available and used by the authors for the purpose of this policy report is the DNV GL Energy Transition Outlook. This outlook is based on a combination of various academic papers, IEA Energy balances, commercial reports and expert judgement. As Figure 2.1 illustrates, fossil fuels currently have a similar share in the current global energy consumption, while in the near future the demand will decrease. First for coal, then around 2025 for oil, and around 2035 also for natural gas. The declining use of these fossil fuels should be largely compensated by increasing use of renewable energy sources, amongst which also bioenergy, see e.g. Figure 2.2.

Fuel substitution often requires installation of a new infrastructure for accommodating the new fuel. It generally also has impact on plant performance and emissions. Several fuel pretreatment technologies have the objective to convert a biomass into a fuel that has technical specifications closer to that of the original fossil fuel, hence reducing the need for new infrastructures and lowering the impact on plant performance.

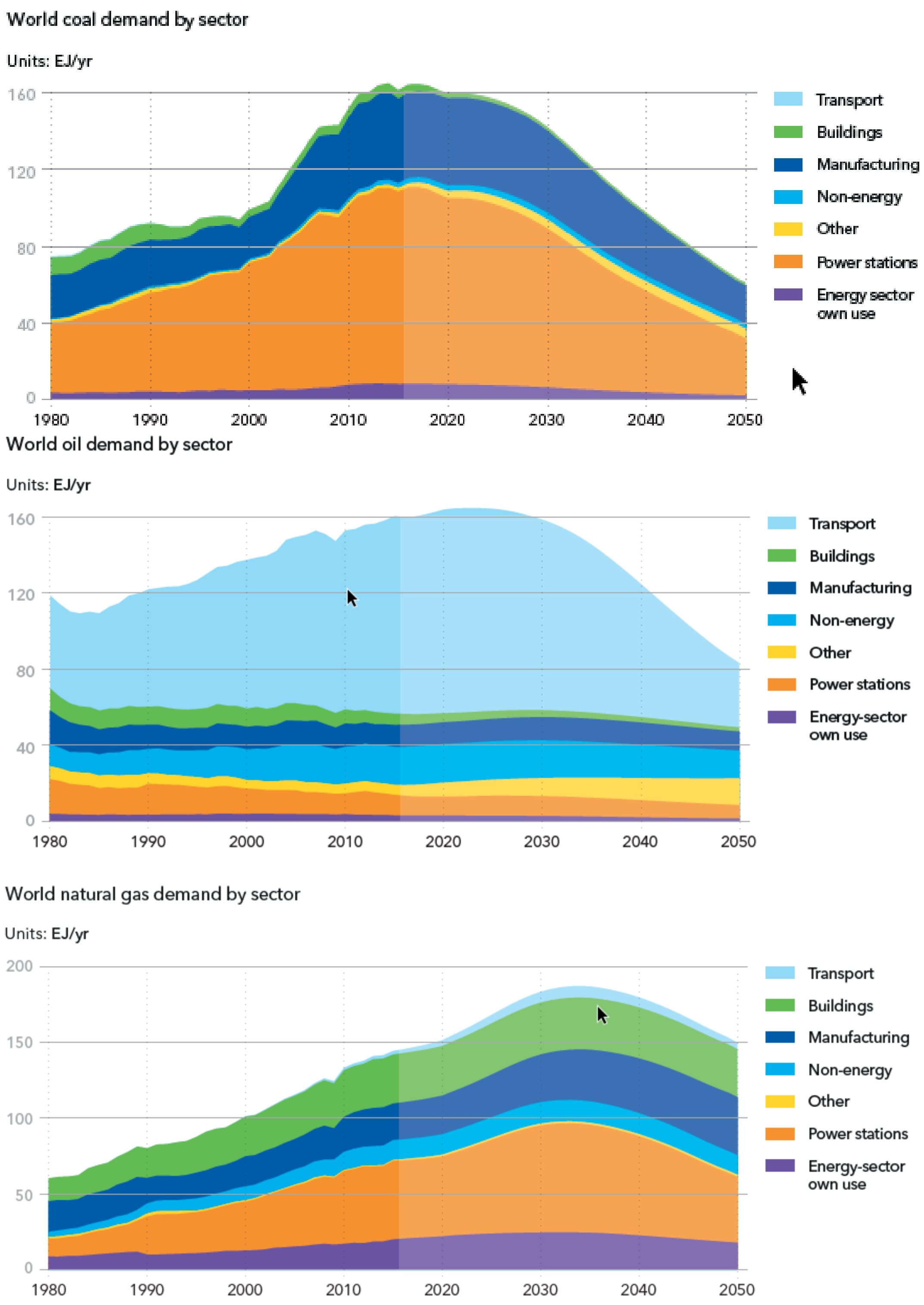

Figure 2.1 Projections for consumption of fossil fuels in various sectors, generated with the Energy Transition Outlook Model (ETOM) (source: DNV GL, Energy Transition Outlook, 2018). The ETOM is a system dynamics simulation model of the global energy system. The equations and parameters in the ETOM are based on academic papers, external databases, commercial reports and expert judgement. Examples of external databases used include the IEA Energy Balances. It also is based on dozens of workshops and discussions with DNV GL industry experts. The results are similar but not exactly equal to IEA's 2DS scenario.

In general, one can state that a biomass fuel that, through a pretreatment process, obtains a higher degree of similarity to an existing fossil fuel results in lower capital requirements associated with plant modification. This becomes attractive if the cost savings in plant modification at the end user are higher than the additional costs of pretreatment. Such a low capex / high opex solution for using a biomass commodity fuel is generally particularly interesting for existing assets with limited expected remaining lifetime or limited expected plant utilization, e.g. older coal fired power stations that are expected to close or be operated as peaking units. Such a preference for a low capex/high opex solution may also arise in case of an uncertain transitional policy environment where it is unclear if more expensive investments in plant modifications will be rewarded over longer periods of time.

An example is the production of black pellets from lignocellulosic biomass, using a torrefaction process (see section 3.1) or steam explosion process (see section 3.4). This results in a fuel that can directly replace coal in an existing pulverized coal fired power plant without significant plant investments, with good grindability, hydrophobicity and a high volumetric energy density.

For coal fired plants that have a longer remaining lifetime or act as a baseload operator, it may turn out to more profitable to convert existing fuel storage, handling and milling systems at the benefit of less expensive white wood pellets. A main rationale for converting raw sawdust into pellets, is to reduce transportation challenges and costs. In the past 20 years the global production of wood pellets for power generation (industrial quality) and for heat supply in the residential market (high quality) has grown rapidly worldwide, totaling more than 26 million tons in 2015 [2]. The case study in section 3.2 shows how a combination of various fuel preparation steps (drying, sieving, chipping and bundling) can result in a reduction of costs for long distance transportation over land for wood residues to end users under Canadian circumstances.

Biomass or waste resources often exhibit large fluctuations in characteristics and composition to allow for direct use in energy plants or for producing a biomass fuel. Removing disturbing impurities is then an essential pretreatment step. The case study in section 3.3 gives the example of a processing technology for converting municipal solid waste into a fuel that can be used in gasifiers. Europe has many good examples of plants producing highly standardized solid recovered fuels from integral municipal solid waste. These recovered fuels are subsequently fed to cement kilns, dedicated power plants and other end user installations.

As Table 1 already indicated, crop residues form a large fraction of our available biomass resources. This type of biomass is however not yet commonly used in thermochemical processes. The chemical behavior in terms of ash and ash melting characteristics is a barrier and the process of leaching lowers this barrier. The case study on leaching (section 3.5) shows a pilot plant research project indicating a positive perspective on commercialization of leaching technologies.

Table 2 Enabling pre-treatment technologies for the use of biomass resources to displace fossil fuels in various sectors [1,3,4,5,6]

Sectors	EJ	Current fuels to be replaced	Biomass requirements	Pretreatment for woody biomass (19-35 EJ)	Pretreatment for herbaceous biomass (49 EJ)	Pretreatment for solid waste (11 EJ)
Electricity	100	Coal	High ash melting point, easy to grind, if possible hydrophobic, low logistical costs	White or black pellets **(case studies 1 and 4)**	Leaching Pellets Black pellets	Separation Drying Gasification Gas cleaning
	60	Gas		Gasifier	Leaching, gasifier	
	10	Oil		pellets, fast pyrolysis oil	Pyrolysis	Pyrolysis
Steel	20	Coal	biomass derived reducing agents	Carbonisation	-	-
Cement kiln	10	Coal (7 EJ), oil, natural gas, biomass/waste	Sufficient heating value and ash composition adequate	--	-	Selection of valorising wastes **(case study 3)**
Other industrial heat	70	Natural gas, oil, coal	Depending on application, easy logistics, reliable	Chips, pellets	Leaching + bales, pellets **(case study 5)**	
Space heating	120	Natural gas, oil	No contamination, high heating value	Chips, pellets **(case study 2)**	Bales, pellets	-

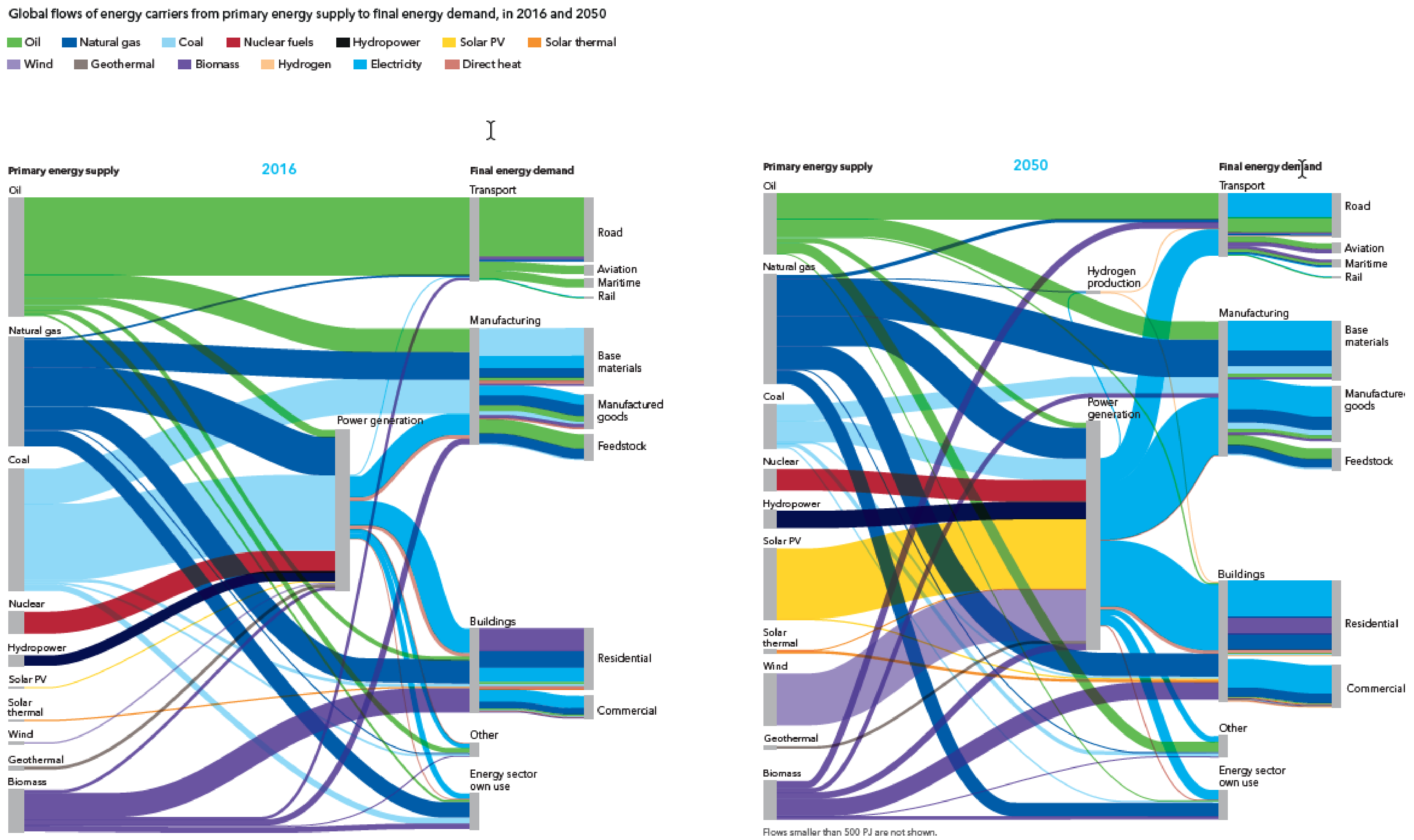

Figure 2.2 Consumption of coal has flattened and is set for continued decline in most of the world, reducing coal demand from 163 EJ in 2016 to 68 EJ in 2050, when it represents 10% of world's energy use (source: DNV GL, Energy Transition Outlook, 2018).

3 Pretreatment technologies assessed

This section shows a brief summary of the pretreatment cases that were assessed in the framework of this IEA Bioenergy intertask study. For each case, a description of the principle is described, followed by its potential impact and a concluding section. The detailed reports are available on the IEA Bioenergy TCP website[2].

3.1 BIOMASS TORREFACTION

The case study '*Biomass torrefaction as alternative to wood pellets for co-firing*'[3] was prepared by Michael Wild (International Biomass Torrefaction Council) and Lotte Visser (Utrecht University). [8]

3.1.1 Principle

Using a torrefaction process, biomass is heated up to a temperature of approx. 225-275°C. At this temperature, not only all water contained in the biomass is evaporated, but also a part of the compounds that are volatile at this temperature which can be used as a fuel to drive the process. As a result, the biomass loses a significant amount (up to some 50%) of its original mass, but with little total energy loss. After densification into pellets or briquettes, it results in a product with a high volumetric energy density, that (in contrast to the original fibrous biomass) is also hydrophobic and easily grindable. It can therefore serve as a direct replacement for coal in power generation and industry, as it is compatible with existing fuel supply infrastructures.

The reduction on logistical costs, in combination with the potential ability of torrefaction to significantly reduce chlorine (Cl) contents of raw biomass, may make it possible on the longer term to use herbaceous agriresidues as a feedstock for torrefied biomass pellets, and use these for power generation in pulverised coal fired power plants.

3.1.2 Potential impact

As Table 2 shows there is an enormous demand for coal for power generation (100 EJ), where torrefied biomass could in principle be used. There are a number of companies currently trying to commercialize torrefaction technologies [7], however it takes time to develop the technology and convince end users about the advantages compared to white wood pellets. As coal is a carbon intensive fuel, the achieved CO_2 savings per GJ are significant if one assumes that these plants will remain in use for the foreseeable future.

This case study shows that there are several advantages of torrefied biomass fuels compared to white wood pellets in terms of CO_2 benefits, energy requirements and costs [8]. In the meantime however several coal fired power stations have already been converted to regular white wood pellets. For these plants it is less interesting to switch to torrefied biomass, as they have already made their investments in converting to white wood pellets. The potential market is therefore mainly in locations where cofiring has been made financially feasible through adequate support instruments, but conversion to white pellets has not yet taken place.

[2] http://itp-fueltreatment.ieabioenergy.com/

[3]

3.1.3 Conclusions

The torrefaction process can in principle convert wood residues into an attractive replacement fuel for existing coal fired power stations, without the need to invest in extensive conversions, and enables options for longer distance transportation of biomass. This enables the unlocking of remote pockets of biomass, particularly when removal of Chlorine also enables the use of herbaceous biomass residues as a feedstock.

In order to make a large impact, it is important that the technology matures quickly, while coal fired power stations are still operating on coal.

3.2 UPGRADING FOREST RESIDUES

The case study '*Moisture, physical property, ash and density management as pre-treatment practices in Canadian forest biomass supply chains*' was prepared by Evelyne Thiffault (BioFuelNet Canada & Laval University), Shahab Sokhansanj, Mahmood Ebadian, Hamid Rezaei, Ehsan Oveisi Bahman Ghiasi, Fahimeh Yazdanpanah (BioFuelNet Canada & University of British Columbia), Antti Asikainen and Johanna Routa (LUKE, Finland). [9]

3.2.1 Principle

Forest biomass residues are characterised by relatively low energy and bulk densities, they are heterogeneous in physical, chemical and thermal properties; high in moisture, mineral and oxygen content; highly hygroscopic and difficult to handle. It is therefore essential to improve the characteristics of these feedstock by appropriate pretreatment options to enable its cost effective transportation and use at a remote end user.

The case study carried out for Canada [9] shows how a combination of various pretreatment options can make the supply chain for forest residues possible:

- moisture management by passive and active drying, covering, blending, and monitoring and modelling of moisture content;
- physical property management by chipping, grinding, sieving and machine visualization;
- ash content management by washing;
- density management by pelletizing.

3.2.2 Potential impact

Large amounts of forest biomass residues become available from existing forest operations. It is estimated that the amount of residues available in selected North American, European and Oceanian countries that are part of the boreal and temperate biomes could reach 5 to 21 EJ per year [9]. Without appropriate pretreatment steps, it is not economically nor technically feasible to use these biomass resources.

3.2.3 Conclusions

Not only technical limitations at the end user dictate what biomass fuel preparation should be done, there may also be various other considerations on fuel harvesting, storage and logistics upstream. The case study from Canada shows clearly that applying a combination of various pretreatment technologies may be necessary to enable its use for energy generation, replacing natural gas or oil based heating systems or electricity generation. Only by applying a set of carefully selected fuel pretreatment technologies, logistical expenses can be reduced to a level that makes the fuel supply chain economically attractive for stakeholders along the chain.

3.3 SRF PRODUCTION FROM WASTE FOR GASIFICATION

The case study '*Pretreatment of municipal solid waste (MSW) for gasification'* was prepared by Dieter Stapf (Karlsruhe Institute of Technology), Giovanni Ciceri (RSE), Inge Johansson (RISE), and Kevin Whitty (University of Utah). [10]

3.3.1 Principle

Table 1 shows that globally there is approx. 11 PJ of municipal solid waste (MSW) available for energy generation. MSW is still to a large extent being landfilled. It therefore makes sense to consider alternative uses, and replace fossil fuels. By its nature, MSW is very heterogeneous both physically and chemically, which creates operational challenges for energy conversion systems. In addition, the physical nature of waste complicates mechanical feeding into such systems. In order for MSW to be used in systems such as gasifiers, it should be pre-treated to remove non-combustible materials, homogenized to minimize operational variations, and ideally transformed to a physical nature compatible with mechanical feeding systems.

Case study report 3 [10] examines technical and economic aspects of MSW pretreatment, focusing on the application of two established technologies, mechanical pretreatment and mechanical-biological pretreatment in Germany and Italy. The evaluation highlights that mechanical and mechanical-biological pretreatment of MSW can allow waste to meet the physical and chemical specifications required of gasification facilities. The pretreatment processes are relatively straightforward and involve several stages of sorting, separating, size reduction, and in some cases, biological treatment. Capital costs for the pretreatment systems are moderate and generally worth the benefit of making a low-cost, readily available feedstock stream available. The overall economic analysis is favorable, but viability depends strongly on received gate/tipping fees associated with collecting the municipal waste.

3.3.2 Potential impact

In principle, the production of SRF from MSW can have a significant impact in reducing fossil fuel consumption in e.g. power generation and cement kilns. A significant fraction of the 11 EJ of MSW that is currently available globally can thus be valorized.

3.3.3 Conclusions

The case study shows that MSW can in principle be turned into a useful fuel with narrowly defined specifications through a carefully selected number of mechanical and mechanical-biological pretreatment processes. The economic feasibility of performing a process however strongly depends on the characteristics of the wastes, the options for using the material and the economic framework conditions.

3.4 STEAM EXPLOSION

The case study '*The steam explosion process technology'* was prepared by Patrick Wolbers (DNV GL), Marcel Cremers (DNV GL), Travis Robinson (NRCan), Sebnem Madrali (NRCan), Guy Tourigny (NRCan). [11]

3.4.1 Principle

The steam explosion process technology is a technology that is known from other applications in the past. In an enclosed vessel, low-grade biomass feedstock that has been comminuted into pieces with acceptable size is saturated by pressurized steam of typically 200-250 °C / 20-40 Bar. After a sudden decompression, steam inside the material expands and breaks apart the material. While the released moisture removes part of the alkaline and chlorine components from the fuel (that are normally problematic during combustion), the resulting fibres become better grindable and hydrophobic because of the high temperature. After pelletisation, a fuel results that is similar to the product of torrefaction (hydrophobic and with a high energy density). There are a few technology developers with operational production plants on woody residues. The technology needs to be proven at scale for non-woody biomass types.

As the case study for use of steam exploded pellets at OPG's Thunder Bay station in Canada shows [11], the product has very similar handling and combustion behavior as coal. It can be stored outdoors for a longer duration with no significant impact on mechanical durability, and can be handled using existing coal handling storage bins and conveyor systems. In the case of the Canadian power plant, the only modification was related to prevention of dust and odor formation, and air installing humidification systems to avoid static discharge between conveyors. The report shows that the production costs of steam explosion pellets are higher than those of wood pellets. This requires specific applications, such as peaking power plants where outdoor storage is permitted and the cost differentiation between wood pellets and steam explosion pellets can be balanced, e.g. by savings on handling equipment.

3.4.2 Potential impact

Steam explosion results in a product that behaves similar to coal, however it can be produced from a sustainably managed biomass resource. As Table 2 shows there is an enormous demand for coal for power generation (100 EJ), where steam exploded biomass could in principle be used. There is a particular niche market for steam exploded pellets in situations where coal is no longer wanted, but the expected remaining plant utilization does not justify significant investments in plant modification to accommodate the use of white wood pellets. This may be the case for peaking or backup power plants fired with coal or plants that approach their closing date.

3.4.3 Conclusions

Similar to torrefaction, steam explosion can in principle convert wood residues into an attractive replacement fuel for existing coal fired power stations, and enable options for longer distance transportation of biomass. This enables the unlocking of remote pockets of biomass, particularly when removal of Chlorine also enables the use of herbaceous biomass residues as a feedstock.

Because of the significantly higher fuel production costs than normal wood pellets, one needs to valorize the advantages of this fuel, that is little or no need for plant modification and somewhat lower transportation costs due to the higher energy density. Similar to the torrefaction process, it is important to get out of the chicken egg problem of a lack of both suppliers and users of the fuel.

3.5 BIOMASS LEACHING

The case study '*Leaching as a biomass pre-treatment method for herbaceous biomass*' was prepared by Koen Meesters, Wolter Elbersen, Pascal van der Hoogt, and Hristo Hristov (Wageningen University & Research). [12]

3.5.1 Principle

Herbaceous biomass originates from plants that typically have a non-woody stem and die at the end of the growing season, in contrast to trees which build up woody biomass over years. For most applications the high inorganic / ash content causes operational problems. Particularly Chlorine (Cl) and Potassium (K) are problematic as it contributes to corrosion and ash melting problems. These components typically need to be reduced by a factor of 10 to 20 in order to comply with current thermal conversion standards. In principle K and Cl (and Na) can easily be removed by leaching with water. An example where this already happens is with straw in Denmark, where weathering by outdoor storage for a longer period of time can significantly improve its combustion behaviour, however practical industrial methods for doing so have not yet been presented.

A case study was done on oil palm empty fruit bunch (EFB) and sugar cane field trash [12]. Both are typically underutilized residues which currently have little uses. Extraction experiments showed that potassium and chloride concentrations can be reduced by 80% respectively 90% after four consecutive extractions with fresh water, bringing Cl and K down or close to acceptable levels. Experiments showed that one kilo of dry matter biomass absorbed approximately 2 litres of water. After 30 minutes (EFB) and 15 minutes (trash) equilibrium was reached and the water was removed. The loss of biomass after 4 washing cycles was 6% DM for EFB and 15% for trash. Using a counter-current extraction system would make it possible to use 3.3 litre water per kg of (DM) biomass to remove 94% of K and Cl in 10 extraction stages. Or 5.4 litre of water in 4 counter-current stages.

The cost of extraction on a scale of 40.000 tons DM (equivalent to a large oil palm mill) was estimated to be approximately 8 US$/ton (6.5 €/ton), which is 5 to 10% of the delivery cost of biomass pellets to European harbours.

3.5.2 Potential impact

While most of the current bioenergy installations are based on woody biomass, large amounts of herbaceous biomass resources are still left unused. Table 1 indicates that there are still about 49 EJ of agriresidues available globally. A good example of a process residue that could be better valorised if potassium and chlorine contents could be lowered using an industrial leaching process is empty fruit bunches from the palm oil industry.

3.5.3 Conclusions

There is a large potential for diversifying the resource base for bioenergy if herbaceous biomass could be better valorized. Industrial leaching has a significant technical and economic potential in this respect, however effort should be made to further develop and commercialize the process from pilot plant scale to commercial scale.

4 Conclusions

Pretreatment methods can be essential for improving or enabling the use of low grade biomass fuels for various thermochemical bioenergy applications. This can help in broadening both the resource base for bioenergy and the end user market. Considering the resource side, particularly herbaceous biomass resources represent a yet underutilised option with a global potential of 49 EJ. On the demand side, coal fired power plants with a demand of 100 EJ of fuel input represent an enormous potential market for cost effective implementation on the short term. Then, there are various smaller biomass/waste streams and end user markets that could also greatly benefit from pretreatment methods.

The advanced pretreatment technologies that are described in this report have several technical advantages over currently available technologies, but some need to be further developed and demonstrated to receive market acceptance, e.g steam explosion, torrefaction and leaching. It is obvious that adequate policy support instruments should be available to accelerate such development. Other technologies such as (natural) drying, weathering, chipping, baling and pelletisation can be regarded as proven technologies.

The case studies that were performed in the framework of this project illustrate that there are various options available for enabling or optimising biomass supply chains, and some of those have been discussed. Pretreatment technologies overcome limiting factors such as chemical composition of the biomass resource, transportation costs or technical limitations at the end user.

Chemical characteristics of the biomass resource may be a limiting factor for the end user, particularly alkaline and chlorine contents as present in herbaceous biomass residues. In this respect, leaching may pose an attractive option to remove part of these components. For example, outdoor weathering of straw has proven to be a cost-effective leaching option. Industrial leaching processes are yet to be commercialised, but pilot plant research indicates that this could become a cost-effective option (at approx. 8 US$/ton). Certain thermal pretreatment processes such as steam explosion or (wet) torrefaction may also be beneficial to remove part of the alkaline components.

The high **transportation costs** associated with some distributed or remote biomass resources may also be a limiting factor. Various pretreatment technologies are available to increase the volumetric energy density of biomass resources, varying in both commercial availability and effectiveness from (natural) drying and chipping to pelletisation and thermal pretreatment. It is evident that the longer the transportation distance, the more attractive it becomes in terms of costs and GHG savings to apply such (advanced) pretreatment options. This is clearly shown in e.g. the case on forestry in Canada and the case on the supply of torrefaction pellets vs. normal wood pellets from Indonesia to Japan.

Substitution of an original design fuel in an existing conversion plant by a biomass fuel may negatively affect operational integrity or performance. Such **limitations in fuel flexibility** may also make it attractive to pretreat biomass resources, instead of investing in a more expensive and fuel flexible energy production plant. This is particularly the case in situations where the required additional capital investments for modification of an existing plant cannot be justified in the framework of expected remaining utilisation, or if such modifications are simply not technically feasible. The cases on steam explosion of wood residues to replace coal in a pulverised coal fired power plant and the case on pretreatment of MSW to prepare Solid Recovered Fuels for gasification illustrate this principle.

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Further Information

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