Case Study 2

Wood Waste to Energy

Case Study for ZWSA

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Sources of Wood Waste

Wood waste is produced by a number of sectors including commercial and industrial (C&I), construction and demolition (C&D) and as part of the municipal waste stream. Wood waste arises via a variety of post-consumer waste and in different fractions, ranging from untreated, pre-consumer off-cuts to treated wood containing preservatives.

A number of organisations are involved in the production of waste wood, its aggregation and its re-processing to forms that are suitable for re-use, recycling or energy recovery:

- **Producers:** wood processing industry, including: furniture manufacture; packaging and pallets; construction and demolition; other industrial and commercial sources; and mixed waste producers, i.e. from the municipal waste stream.
- **Aggregators: Recyclers and re-processors** (who sort, segregate and process the waste wood for subsequent markets)
- **Users:** panel board manufacture; energy generation; animal bedding; horticultural use.
- **Treatment, energy recovery or disposal** of waste wood that cannot be recycled or recovered: landfill and energy from waste.

Energy Potential of Wood Waste

Wood waste, and wood by-products from industry that cannot be recycled or reused, are often recovered for energy use through combustion processes. Across the EU, it is estimated that wood waste from municipal sources contributes approximately 60 terawatt hours (TWh) from Europe's total biomass[1] energy supply. Forestry by-products (such as black liquor, sawdust, and bark) contribute approximately 380 TWh to the total energy supply. For context, the total domestic biomass supply is approximately 1,000 TWh primary energy per year.[2]

European Waste Incineration Directive

Contaminated waste wood is mainly landfilled or incinerated. In Europe, the thermal treatment of waste is governed by the Waste Incineration Directive (WID), which sets emission limit values and monitoring requirements for pollutants to air such as dust, nitrogen oxides (NOx), sulphur dioxide (SO_2), hydrogen chloride (HCl), hydrogen fluoride (HF), heavy metals and dioxins and furans. At present, clean

[1] The definition of biomass is "the biodegradable fraction of products, wastes, and residues from biological origin from agriculture (including vegetable and animal substances), forestry, and related industries including fisheries and aquaculture, as well as the biodegradable fraction of waste" (Renewable energy directive, 2009/28/EC).
[2] http://www.europeanclimate.org/documents/Biomass_report_-_Final.pdf

recovered wood (free from halogenated organics and heavy metals) can be burnt outside the restrictions of the WID. The levels of contamination found in most waste wood means treatment plants must be WID compliant. Treated waste wood includes any wood with a surface coating such as paint, varnish or preservatives. WID requires that combustion of treated wood waste meets strict emissions limits. Therefore, it is possible to recover energy from treated and contaminated wood, but only where pollution abatement is installed to ensure emissions fall within the WID limits. The main requirements of WID are:

- Combustion gas must be raised to 850°C for 2 seconds;
- For hazardous waste with more than 1% of halogenated organic substances, expressed as chlorine, the temperature must be raised to 1,100°C for 2 seconds;
- Residence time and temperature need to be demonstrated.

There are also air emissions requirements including limits on the emissions of dust, total organic carbon, Hydrogen chlorine (HCl), Hydrogen fluoride (HF), Sulphur dioxide (SO2), Nitrogen monoxide (NO) and nitrogen dioxide (NO2), heavy metals and dioxins.

There is no lower threshold in terms of the quantity of waste combusted. The cost of complying with WID is prohibitive for smaller facilities, and therefore only larger facilities are likely to accept waste wood. WID is seen as a barrier to the recovery of energy from waste wood, and many facilities are designed to accept wood which is not deemed waste. In the UK, a grading system has been developed to classify wood into high quality (Grade A) and lower quality wood (B to D). WID compliant combustion plants can be used to recover energy from Grades B, C and hazardous waste wood (as well as Grade A), providing an alternative to landfilling for these grades.[3]

Energy Recovery Options for Waste Wood

The use of waste wood for energy is high in countries such as the US, Canada and Europe.

The following provides a broad overview of typical technology options:

- Technologies range from small boiler systems for directly heating houses and apartment buildings up to biomass boilers that efficiently supply heat through district heating networks.
- Wood waste, along with other biomass, is also used to generate electricity in combined heat and power plants (CHP). The waste heat produced is utilised in local and district heating networks or made available to industry as process heat. It can also be used to produce cooling for industrial purposes, for refrigerated warehouses or for cooling buildings (if combined with CHP, this is called tri-generation).
- Wood waste gasifiers may be used to generate heat and electricity. Depending on the characteristics of the combustion material and the capacity of the system, fixed bed, fluidised bed or entrained flow gasifiers can be used. The resulting syngas is then used to produce electricity in combustion engine systems or gas turbines.

Wood waste markets

Markets for waste wood depend very much on the type and quality of the wood. Other than energy recovery, other markets include panel board manufacturing, animal bedding, equine surfacing and use in agriculture and horticulture. In general, recycling outlets such as these require higher grades of waste wood. This high quality can be achieved by either front end sorting or segregation, or by processing the wood further after it has been collected.

Large producers of waste wood, for example panelboard manufacturers and saw mills typically have established markets for their waste wood or ‘co-products’. In the UK it is common for large furniture manufacturers to use waste wood to generate process heat to be used in the manufacturing process.

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[3] http://www.defra.gov.uk/consult/files/consult-wood-waste-researchreview-20120731.pdf

Markets for waste wood can be volatile, for example in a period of economic downturn and when there is a fall in construction projects there is less demand for waste wood to manufacture panel board, and therefore demand and market value may fall.

Identification and segregation

One of the main barriers to the use of wood for energy recovery or in other markets is the uncertainty of the type and grade of wood. It is difficult to effectively segregate waste wood from municipal waste streams due to the wide variety in the type and quantity of waste wood present. Whilst it may be easier to segregate waste wood at transfer stations or recycling centres, it is still difficult to identify if waste wood has been treated with paints or preservatives.

Energy recovery has an advantage over other recycling outlets in that it is able to accept higher level of contaminants, and is sometimes the only available option other than landfill. For example, animal bedding manufacturers will require a waste wood stream that is free from contaminants.

Economic Drivers

Recovery of energy from waste wood will only become financially attractive when costs are lower than landfill. Whilst higher grades of wood may be sought after, the disposal in landfill of lower grade waste wood may still be the cheapest option.

Unlike other renewables such as wind and solar, waste wood either needs to be segregated and collected, or grown, harvested, processed and transported to the end user. All of this activity will incur costs.

For waste wood to be segregated, it also needs to be financially viable. For example, there needs to be significant savings compared to landfill for the construction and demolition industry to install separate skips to separate wood waste from other waste materials.

The value of waste wood as a fuel must also be taken into consideration when evaluating the economic feasibility of a waste wood project. The fuel potential of waste wood will vary significantly, depending on the source. Fuel potential is directly linked to moisture content. In general, waste wood from construction and demolition or commercial and industrial sources will have lower moisture content than forestry and biomass crops.

Security of supply

The long term security of supply is a central concern to investors in biomass projects. It is for this reason that many plants have been designed to utilise clean, forestry residues and other such materials, as opposed to relying on other sources of waste wood which may have a more complex supply chain. It is also easier to obtain long term contracts for forestry and biomass crops as sources will be more predictable over the long term than waste wood from household, commercial and industrial sources. Developers may need to seek multiple supply contracts to reduce the risk of exposure to one supplier. It is also good practice to keep a reserve of fuel on site, to act as a buffer to allow for any interruption to supply.

Wood waste to energy case studies

The following brief case studies examples demonstrate how waste wood and non-recyclable wood by-products may be utilised to generate heat and power.

Wood Fired Combined Heat and Power Plant (Germany)

In 2001, a new biomass fired combined heat and power (CHP) plant fuelled by forestry and wood residues from sawmills was commissioned in the town of Pfaffenhofen, Germany (population approximately 22,000).[4]

The plant produces process steam, process heat, district heat, and space and process cooling, as well as electricity and was regarded as one of the most innovative and advanced plants in Germany.

The plant supplies a newly erected district heating grid with steam and hot water. The maximum thermal power output is 32.5 MW, supplying heat via a district heating network to a hospital, schools, and other public and private buildings. Furthermore, the plant delivers process steam for a large biological baby food factory. The plant supplies 6.1MW electricity for the grid and the calorific value of the fuel is 9.07 MJ/kg (moisture content 45%).[5]

Total investment costs totalled €49 million and were financed by a combination of private finance, equity, government investment grants and bank loans. In 2000 the Federal Government adopted the new Renewable Energy Sources Act. The Act provides guaranteed, absolute minimum feed-in tariffs that the grid operator has to pay for a period of 20 years after commissioning the plant. The introduction of this new law improved the cost effectiveness of the plant significantly. When the plant was commissioned in 2001 it was eligible for a feed in tariff of 9.3 Eurocents/kWh. The amendments to the Renewable Energy Sources Act in 2004 saw further bonuses to be paid on top of the regular feed-in tariff provided the electricity is exclusively produced from wood and other replenishing raw materials. The ability of the plant to secure heat customers and sell almost all of the residual heat to domestic and commercial users further improved the project economics.

The plant was originally designed to combust forest and sawmills residues, using an initial ration of 30 per cent wood chips and 70 per cent sawmill residues. However, by 2003 this ratio was reversed because changes in pricing and improved fuel logistics. Since 2004 the plant uses exclusively forest residues (90 per cent) and woodchips from landscape protection and management (10 per cent). This was due to a subsidy for electricity produced in plants exclusively using wood and other replenishing raw materials that was introduced in 2004

- Benefits:
  - Annual CO_2 savings of 65,000-70,000 tonnes
  - 90% of ash is reused in the agricultural and forest sector as a fertiliser
  - Local employment created in fuel supply chain
- Success Factors
  - On-going political commitment and support by the municipal and district authorities
  - Ability of boiler to combust different types of fuel, enabling a switch to a more cost effective fuel.
  - Fuel supply risk is minimised by using a large number of suppliers.
  - Supported by The German Federal Ministry of Environment via its Investment Programme for Reduction of Environmental Loads

[4] http://www.volund.dk/Biomass_energy/References/Pfaffenhofen
[5] http://www.reg-energy.org/data/dokumente/re18_c4_compilation_case_studies_30_300ie.pdf

- Policy support measures include an investment grant, an interest subsidy loan and increasingly attractive remuneration rates for electricity produced
- Social acceptance to the facility was initially very low. The project sponsors and local authorities worked closely together to deliver a counter-initiative in support of the plant. The project was supported by all parties in the local city council. Information and education convinced the public of the advantages of the plant, which gained the majority of votes in a referendum in 1998.

Wood Waste Gasification – Austria

The Güssing Biomass CHP Plant (Austria), which started operation in 2002, is one of the most successful demonstration plants in Europe. It consists of a steam-blown fluidised bed gasifier to produce nitrogen-free biogas for electricity generation and district heating distributed in the city of Güssing.

The plant achieves an electrical production of 2 MW from 8 MW of input biomass, through a biomass gasifier coupled with an Internal Combustion (IC) gas engine with an electrical efficiency of 25% and a heat efficiency of almost 50%. The gasification plant produces 4.5 MW of heat for the local district heating network.[6]

In the gasification zone, at approximately 850°C, the biomass is gasified with steam. By using steam instead of air, the resulting gas has a lower tar content and a higher heating value (12 MJ/Nm^3). The gas engine is a turbo-charged "Otto"-type engine from GE Jenbacher that had been specially adapted to the properties of the producer gas.[7]

More than 45% of the surrounding area of Güssing is forested. Ownership of the forestry is divided up between several hundred farmers. The municipality ensures that the farmers manage their area of forest. The plant uses agricultural and forestry residues and wood from the region with a moisture content of 20-30%. The quantity of fuel consumed is approximately 2,300 kg/hour.[8] The plant consists of a dual fluidized bed steam gasifier, a two-stage gas cleaning system, a gas engine with an electricity generator and a heat utilisation system.

The cost of the demonstration plant was approximately €10M, with €6M funded nationally and by the European Union. Operation costs are approximately 15% of the investment costs. The district heating system is 27 km in length and services 300 houses, 50 building public building and 10 industrial applications.[6] Electricity is sold to the local electrical grid operator for which a feed-in tariff is received. The plant produces enough electricity to meet the entire needs of the city. The energy framework in Austria ensures the economic efficiency of the plant. Whilst fuel costs are high, this is offset by the high feed in tariffs for electricity.

- Benefits:
  - 93% reduction in Co2 emissions
  - Creation of 1,000 new jobs in a small town of only 4,000 people
  - The Güssing CHP-plant enables the complete renewable energy supply to the city
  - The use of local raw material ensures a higher price is paid
  - The city's energy supply is now independent from fossil fuels and the associated price fluctuations

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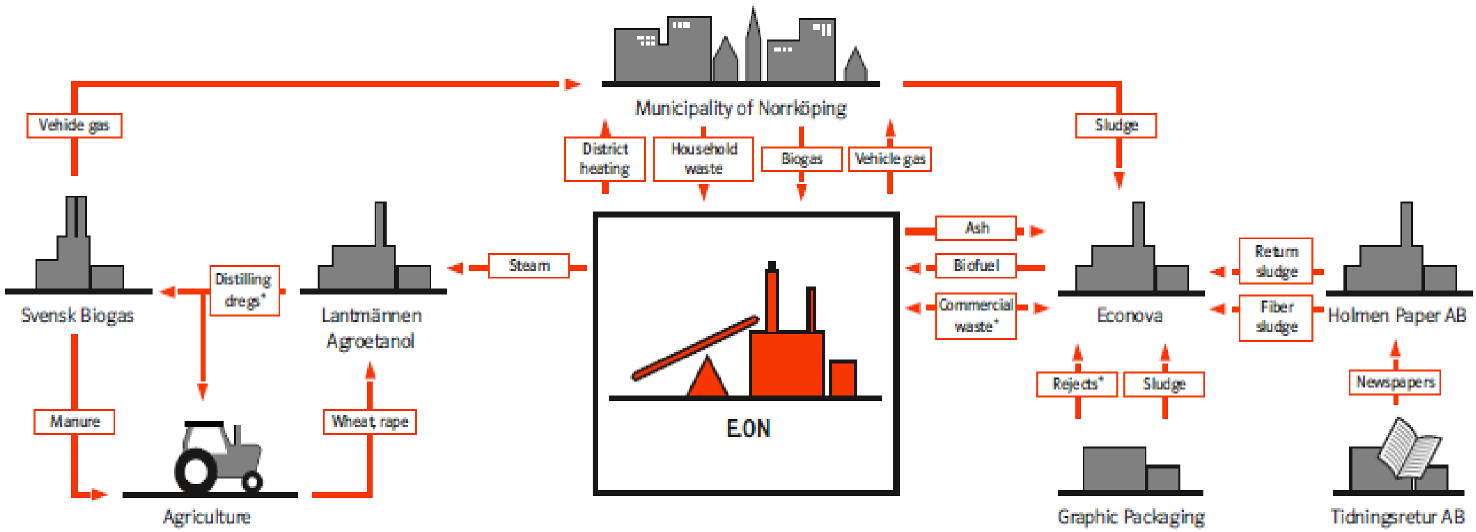
[6] http://www.supergen-bioenergy.net/Resources/user/docs/08%20Hofbauer-%20Birmingham.pdf
[7] http://www.zukunftsenergien.de/hp2/eu-project/downloads/aichernig-paper.pdf
[8] http://www.renet.at/english/gussing-biomass-heat-and-power-plant/

- Success Factors
    - Sufficient sources of biomass available locally
    - Independent company formed to collect and transfer waste wood from farmers
    - Biomass secured in long term contracts
    - Municipality
    - Municipality supported investment in research and development
    - European Centre for Renewable Energy was formed to coordinate the development, and to continue to develop solutions for regional and community based renewable energy generation and use

EON Combined Heat and Power Plant, Händelö, Sweden



** Distilling dregs - Waste product from the production of ethanol in the form of high-protein mash.*
Commercial waste - Waste from operations.
Rejects - Plastic film and similar material from the recycling of cardboard, for example, milk packaging.

www.eon.se

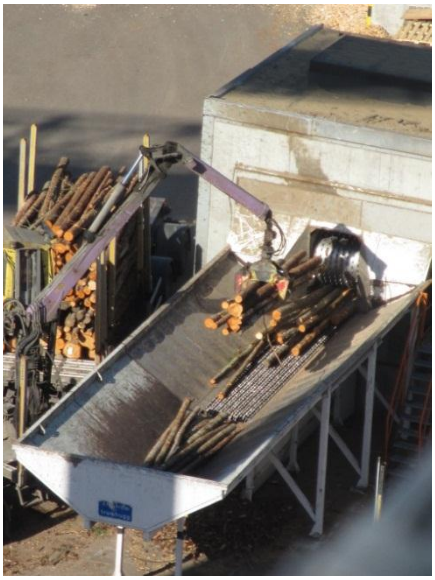
In the Händelö industrial area just outside the city of Norrköping in Sweden is a cluster of energy facilities. The complex is based on the synergies that can be realised by utilising each other's by-products in a concept known as industrial symbiosis.

At the heart of the complex is the EON co-generation plant, a combined heat and power plant which uses a wide mix of waste derived fuels to produce energy, heat and steam. The fuel mix is based on 95 per cent renewable fuels, which include forest residue, wood waste and municipal waste. Heat is delivered to the district heating network, electricity to the local electricity grid, and steam is used at the adjacent ethanol production plant (Agroetanol). The steam sold by EON to Agroethanol meets almost all of its energy needs.

The ethanol plant uses corn, wheat and rye in its production. Distiller's grain, the by-product of ethanol manufacturing, is used to produce protein pellets, among others, i.e. animal feed.

In a further example of industrial symbiosis, the waste distilling grain from the plant is used at a nearby biogas plant. The AD plant, operated by Svensk Biogas utilises the waste grain from the ethanol plant as a feedstock in addition to other crops. Svensk Biogas then produces vehicle biogas and bio-fertilizer for the agriculture sector.

There are five boilers at the Händelö plant, two of which are configured to process wood waste. One of these is a 90MW vibrating grate boiler, which combusts both virgin wood and waste wood from the construction industry. The second boiler utilising wood waste is a 130 MW Circulating Fluidised Bed (CFB) boiler. In the CFB technology, combustion takes places in hot, fluidized sand at 850°C, achieving a high combustion efficiency as well as high environmental performance. Both of the boilers using wood waste have efficient flue gas condensation plant, which contributes to the high efficiency of the facility.



- Benefits
  - Maximising the use of energy by the co-location of utilities and industries
  - Closed loop, industrial energy ecology
  - Provides solution for waste wood produced in the area by businesses and households
  - 129 MW electricity produced by the plant
- Success Factors
  - The energy complex makes use of local resources, and generates a greater exchange of energy and maximum use of materials than each company could achieve individually
  - This has been made possible by the mutual trust and cooperation of the businesses involved, and the cohesion of their business models.

O-gen Small Scale Waste Wood Gasification, UK

O-Gen was formed as a company in 2005 to develop a treatment for waste timber, including chipboard.

O-gen has developed strong relationships with funders and investors to drive future deployment of their gasification technology in the UK. O-Gen have also secured long term power purchase agreements for the electricity produced at all future O-Gen facilities, in order to mitigate against any potential risks in the sale of electricity.

In the UK, the passing of the 2008 Energy Bill meant that the Renewables Obligation (RO) became the principal mechanism for incentivising the production of renewable electricity. A requirement was placed on electricity suppliers to purchase enough Renewable Obligation Certificates (ROCs) to meet their obligations. ROCs were banding to award different levels of ROCs, depending on the efficiency of the technology. The most advanced and efficient technologies such as advanced thermal technologies were allocated 2x ROCs per MWh. O-Gen developed the first biomass gasification plant in the UK to be awarded the maximum ROCs per MWh.

The first project developed by O-Gen is located in Stoke-on-Trent, Staffordshire, and has a capacity to export 3MW of electricity by gasifying 3 tonnes of timber per hour. The plant comprises of 12 small-scale downdraft gasifiers. Special modifications have been made to the equipment by O-Gen, in order to be able to cope with nails and screws, small stones and other contaminants to be commonly found in timber waste. The timber is gasified in to a clean syngas, which is subsequently combusted in a series of six gas engines.

O-Gen is purposefully designing their facilities to be small scale in comparison to major electricity producers. The plants can provide local grid connections to power industry and housing at a local level. They aim is to roll-out the development of an estimated 15 plants with a total capacity of 50MW.

Building on the success of the first demonstration plant, a further facility has been built in Derby, and an additional 40,000 tonne capacity plant which will treat wood waste and supply both heat and power is to be built in Plymouth, UK. This facility will generate around 26,000 MWh of electricity a year - enough to power 6200 homes. In addition to benefiting from double ROCs, the project will also benefit from the Renewable Heat Incentive (RHI) tariff for heat exported.

- Benefits
    - Small scale, local solution to timber waste
    - Flexible, modular technology
    - Small footprint and can be installed on small areas of land
    - Can be located close to feedstock supply
    - Minimal visual impact on environment and can be installed in purpose built buildings
    - Proposed facility in Plymouth will create 23 local jobs, and 50 jobs during the construction phase
- Success Factors
    - Plant designed to accept contaminants in the timber waste
    - Electrical energy produced is eligible for two ROCs per MWh under the Renewables Obligation
    - £525,000 grant awarded by South West Regional Development Agency (SWERDA) for the development of a facility in Plymouth.