ABSTRACT

The growing international interest in utilising renewable fuels is demanding new approaches from the energy producers. Biomasses are being more commonly utilised in multi-fuel applications. Main reasons for this are the objectives to reduce CO₂ emissions, and to meet the emission limits of the LCP directive for NOₓ and SO₂. Co-firing, defined as simultaneous combustion of different fuels in the same boiler, provides an alternative to achieve emission reductions. This is not only accomplished by replacing fossil fuel with biomass, but also as a result from interaction of fuel reactants of different origin. At the same time, direct combustion is often competing towards gasification and its many applications. Both of these technologies have their benefits, and thus many Finnish enterprises have developed their specific technologies for the growing market.

INTRODUCTION

Biomass utilization in its various forms has gained reputation as one of the most promising methods to tackle the CO₂ issue, which has risen to slow down the rate new fossil fuel units are being built. Addition of biomass as a secondary fuel into existing fossil fuel units has been widely studied, and units capable of burning a 100% biomass share have been built in a large scale; for instance, the Alholmens
Kraft, a 240 MW$_e$ CFB boiler located in Pietarsaari, Finland can be operated with different biomass-based fuels up to full load, see Figure 1.

![Image](image1.png)

**Figure 1.** The Alholmens Kraft CFB boiler in the Western Finland is the World's largest biomass CHP (Combined Heat and Power) unit, figure by Metso Power.

The use of biomass fuels is not as straightforward as it may seem: When cofiring biomass fuels with fossil fuels, following implications may be expected: increased rate of deposit formation, shorter soot-blowing interval, bed material agglomeration, increased risk of corrosion, higher in-house power consumption etc. Deposit formation inhibits heat transfer and reduces boiler efficiency, and additionally, chlorine rich deposits may induce hot corrosion of heat transfer
surfaces. Due to this, operating and maintenance costs may increase, but this can be diminished or even avoided with appropriate fuel blend and process control.

**ROLE OF BIOMASS IN FINLAND**

Finland is the world leader in utilisation of bioenergy. Wood-derived fuels cover 20% of the primary energy consumption, and 10% of the electricity consumption in Finland. The forest industry dominates the use of wood-based energy production: about 80% of the wood-derived fuels are by-products and residues from the forest industry. With these figures, Finland tops the list of bioenergy use in Europe. In the Action Plan for Renewable Energy Sources (1999), the Finnish Ministry of Trade and Industry set a target of increasing the use of renewables by 50% from the 1995 level by 2010. This increase corresponds 3 Mtoe (125 PJ), of which 90% was estimated to be covered by bioenergy. In December 2002, the Action Plan was revised, and more ambitious targets were set. According to the new targets, the use of renewables should be increased by 30% from the 2001 level by the end of 2010, being almost 10 Mtoe (412 PJ).

Most of the bioenergy in Finland is produced in connection with wood industries. In addition to this, most communities use biomass-based fuel in local CHP units. These units can be found in sizes from under one MWₑ to 240 MWₑ. A typical Finnish co-generation unit utilises local fuels, and is capable of multi-fuel operation, see Figure 2. This applies also to gasification units. The role of biomass pellets is increasing, because compression and drying of the fuel increases the profitability of transport, allowing units bigger than the existing infrastructure would permit, especially in areas where wood industries have a small role as fuel resources.
SOME EXAMPLES OF FINNISH BIOMASS COMBUSTION TECHNOLOGIES

Several companies operating in Finland have developed special products for efficient utilisation of biomass fuels in different sizes. Grate-fired units are very suitable in the small and medium size, and as the unit size increases, fluidised bed units become more common. Figure 3 and Figure 4 show examples of small-to-
medium-scale units. Earlier in Figure 1 was shown an excellent example of a very large scale biomass CHP unit.

![Figure 3. A modern biomass grate combustor, figure by Wärtsilä Power.](image1)

![Figure 4. Principle of a small scale BFB unit by Putkimaa Oy.](image2)

The tendency in very large co-combustion CHP units is to use the fossil fuel as the main fuel, and use a relatively small (up to 20%) biomass share. There are two reasons for this: it is very difficult to gather and transport more than 100 MWth worth biomass without existing infrastructure, and a large biomass fraction may cause operational difficulties mentioned in the introduction. This leads to an approach shown in Figure 5, where the boiler efficiency is increased at the same time as a part of the fossil fuel is replaced with a biomass fuel. This approach allows significant reduction of the CO₂ emissions without leading to high increases in the investment and fuel handling costs. Such a CHP unit is now being build in Poland by Foster Wheeler, the scale of this power plant is 460 MWₑ, and it has biomass burning capability up to a 20% of the thermal load.
Figure 5. A modern approach to reduce the CO₂ emissions by simultaneous increase in efficiency and biomass co-combustion capability, figure by VTT.

BIOMASS GASIFICATION

In addition to direct combustion of biomass, several gasification technologies for CHP applications have been developed. Gasification is a process in which the fuel is heated in the presence of some oxygen or steam into a temperature where the solid or liquid fuel components are broken to gaseous components, see Figure 6. These components include H₂, CO, CH₄ and other hydrocarbons. Some tars may still remain after the initial gasification process, and also N₂, H₂O and CO₂ in gaseous form can be found. The share of the combustible components in the product gas depends on the gasification technology, see Figure 6 for examples of different technologies available for gasification. The product gas may have a very high heating value, especially in steam or oxygen gasification. The product gas can be burned or used as a raw material in a chemical process.
Figure 6. The main principle of producing fuel gas or syngas by a gasification process, figure by VTT.

Figure 7. Different technologies for gasification, figure from a presentation by Hulkkonen S.
NEW FINNISH BIOMASS GASIFICATION EXPERIENCES

In order to promote the utilisation of biomass fuels, several special approaches have been taken. In addition to biomass fuels, some recycled fuels have been gasified with good success. In the early 1980’s, a simple fixed bed gasifier called Bioneer was developed, and it proved to be a good solution for small-scale energy production. This product was developed further, and a Novel gasifier was born, see Figure 8. The utilisation of this gasifier is now being tested at a CHP power plant in Kokemäki, where the product gas is treated with a tar reformer, cleaned with a sophisticated gas cleaning system, and burned in gas engines to provide electricity, see Figure 9.
Gasification has been used for energy production in a bit larger scale in Lahti since 1998. The idea is brilliant: the circulating fluidised bed gasifier is used as a fuel pre-treatment unit, see Figure 10. This allows utilisation of different renewable fuel fractions in a PC boiler without major modifications in the fuel system itself. The product gas is led without cooling directly to a special burner located at the lowest burner level. This allows the residual gases to go through the flame frontier of the coal burners, thus allowing natural reduction in the NO\textsubscript{x} emissions. Replacing a part of the fossil fuel also significantly reduces the CO\textsubscript{2} emissions of the power plant, and at the same time allows a high efficiency; much higher than normally is possible in units utilising renewable fuels.
A special approach in the utilisation of gasification process has been used to treat liquid package residue in the town of Varkaus located in the Eastern Finland. This approach was taken when it was noticed that the metallic aluminium in the material caused heavy fouling and corrosion if the reject was combusted in an existing power plant. In a fluidised bed gasifier, the metallic Al reacts with the bed material, and can thus be removed from the gases without any additional means. This saves the boiler used for gas combustion from fouling and corrosion, and the mixture of the bed material and Al can be used as a raw material for Al production, the process is illustrated in Figure 11.
The latest development in biomass gasification is going to make a big change in the utilisation of wood-based fuels in Finland. A pressurised gasifier with a very advanced gas cleaning can produce syngas, which can be further refined with for instance a Fischer-Tropsch synthesis to produce liquid biofuels for transport. Such a system is being tested and developed at VTT in co-operation with several Finnish companies. This gasifier is to be integrated in the pulp and paper mill process. This allows efficient utilisation of all the side products and heat from the process, thus enabling a very high overall efficiency. The actual plant is planned to be in operation by the year 2012. An illustration of such a plant is shown in Figure 12.
BIOENERGY RESEARCH AT VTT

With a well established expertise in bioenergy, VTT is in a key position in co-operation with industry and other stakeholders to develop the new technology needed to achieve this goal. Through international co-operation, VTT is networking with R&D institutions and industrial partners worldwide. VTT’s research activities in bioenergy cover for instance:

- Fuel processing and handling
- Biomass fuel production
- Liquid biofuel technologies
- Recovered fuel technologies
- Pellet and briquette production
- Recovered fuels.
GASIFICATION RESEARCH AT VTT

Biomass gasification is one of the key technologies of VTT in the area of sustainable energy production. Our aim is to develop new, more efficient and environmentally friendly energy production technologies based on biomass and waste gasification. A major part of our work is process development work, which we can carry out from laboratory to pilot scale with our unique test facilities and world-class expertise. In co-operation with our clients and industrial partners, we are also involved in several European demonstration and commercial projects. In addition, VTT carries out technical and economic feasibility studies related to different gasification processes and applications.

SUMMARY

Finland as the forerunner in development of bioenergy applications has a long history in utilisation of biomass, and especially in co-combustion and gasification. Today, biomasses are being more commonly utilised in multi-fuel applications. Co-firing, defined as simultaneous combustion of different fuels in the same boiler, provides an alternative to achieve significant CO$_2$ emission reductions. Technologies from small-scale combustion to very large scale units are readily available from several manufacturers. These technologies include grate-fired units, fluidized bed combustors and gasifiers, and special applications for most demanding fuels. In addition to this, the whole biofuel chain from cultivation and harvesting to transport and storage, as well as fuel blending has been well researched. This knowledge allows Finnish companies to be the World leaders in biomass utilisation, and provide all customers turn-key solutions even for the most challenging needs.
REFERENCES


3. Nieminen M., Finnish gasification activities, industrial experiences and ongoing R&D projects, presentation material by VTT, Finland