Bio-refining

Executive Summary

Bio-refining is neither new nor revolutionary. The full spectrum in bio-refining from basic bioenergy to pulp, solid and liquid biofuels, bio-based chemicals and bio-based materials (including paper) is advancing on every front and integrating into a whole.

Let’s welcome bio-refining – the next step in the evolution of the pulp and paper industry. It not only addresses numerous global challenges but can also provide new revenue streams for companies across various industry sectors.

When boosting sustainability and eco-efficient energy production, nothing of value should be wasted. Non-recyclable waste can be a valuable fuel for energy production. The main benefit of waste gasification, compared to other waste-to-energy processes, is the higher electrical efficiency that gasification offers.

Using Valmet’s bio-gasification technology, a plant can reduce the use of fossil fuels by close to half and reduce CO₂ emissions. Another possible potential is turning a fluidized bed boiler at a power plant into a bio-refinery incorporating pyrolysis technology. Finally, Valmet is focusing on developing processes and equipment in three main routes where the end products are second-generation bio-based transportation fuels, chemicals and materials via concentrated acid hydrolysis of biomass and green coal.
The four waves of bio-refining

(The "Four Waves" section of this white paper is based on an article written by Dr. Petri Vasara; Global Practice Head, Pöyry Management Consulting for Valmet’s 2013 Results Magazine)

For sustainability, vague and foggy speech with a sprinkling of "green" and "sustainability" often passes for insight. This is an insult to a very significant topic. Fortunately, bio-refining has not yet become a content-free buzzword.

However, trends reign. In a recent analysis quoted in the journal Nature online, it was shown, based on 320 000 articles, that scientists—in this case physicists—are flocking to the topic others are already pursuing. This isn't exactly news, but it is nice to have one's prejudices confirmed. Bio-refining is also in danger of becoming fashionable and simply a word bandied about to make something sound more current and interesting.

Very decentralized biomass

As it so happens, bio-refining is neither new nor revolutionary. At Pöyry, we divide its life cycle into four waves. The first wave, Very Decentralized Biomass, lasted from ancient times to the Second World War. It was simply a question of using the available biomass for the greatest need with the Best Available Technology (BAT). Covering a pile of wood with dirt and igniting the wood (the earth kiln) was for a long time the BAT. The way in which biomass was refined into pulp and paper also had its BAT. The bioenergy supply chain was people collecting firewood.

Wartime innovation

With the Second World War resource scarcity became an issue. The second wave, Wartime Innovation, came about with, for example, biogas-driven cars and ethanol from wood, such as at Domsjö. As the war came to an end so did the extraordinary war-based efforts; and thus ceased the "Project Manhattans".

Oil substitution

In the 1970s, a severe political/oil crisis took place. The third wave, Oil Substitution, emerged, and much of current bio-refining knowledge was created at that time or at least has its roots there. Of course, the crisis passed and many important studies were later destroyed due to the lack of archive space. These studies now have to be tracked down by calling on retirees and asking them if they just happen to have copies somewhere in their basements.

Reinventing bio-refining

We are now in the fourth wave, Reinventing Bio-refining. Partly due to the issue of climate change, and partly due to resource scarcity and political security of supply, the world has spent the last few years somewhat reinventing the second and third waves, often blithely ignoring the work that has already been done. At the same time, a bewildering array of different value-from-biomass projects have been created to compete for attention. Subsidies have boosted some branches of products, and some have subsided, leaving uncertainty in their wake.

What remains as a solid foundation is that in a resource-scarce world, renewable, sustainably produced biomass is a golden asset. The panoply of products and processes is also arranging itself. The full spectrum
in bio-refining from basic bioenergy to pulp, solid and liquid biofuels, bio-based chemicals and bio-based materials (including paper) is advancing on every front and integrating into a whole.

"The King of the Hill" is the one who understands biomass from waste to agro and wood, masters the technologies and processes, and is able to decide on the optimal use to add value. Such a king has every possibility to breach previous cluster limits and expand from the current paper chain to a basis for many key industry sectors. The throne awaits...

**Bio-refining means creating more value from biomass**

The bio-based economy is considered a way of creating a sustainable future. It not only addresses numerous global challenges but can also provide new revenue streams for companies across various industry sectors. Let’s welcome bio-refining – the next step in the evolution of the pulp and paper industry.

"We are looking into bio-refining not only because of our love of technology but also because the world really needs new solutions. This area of business is driven by challenging global issues: climate change, increasing need for energy, energy security, and rural welfare. Therefore, bio-refining is urgently needed but it can only be part of the solution," says Marita Niemelä, D.Sc. (Tech.), the first Vice President of Bio-Technologies of Pulp, Paper and Power segment, Valmet.

Niemelä, who started in her position in November 2012, has an impressive career in biomass and related processing technologies, business consultation, strategy development, marketing and sales. She came to Valmet, formerly Metso from Pöyry and has published dozens of articles on biotechnology. She is also a Docent at the Aalto University School of Chemical Technology in Finland.

**A fresh perspective on existing technology**

In its operations, Valmet has defined bio-refining as the sustainable processing of non-food biomass into marketable products such as pulp, paper, heat, power, fuels, chemicals and bio-based materials such as composites. The company uses the term biomass to mean woody biomass, recycled paper, agricultural residues, purposely grown energy crops and combustible sorted waste.

"Bio-refining with our processes and technologies provides our customers with increased value from biomass. Good examples of our present bio-refining technologies are pulp mills and power plants," Niemelä adds. "Biotechnology is largely about further developing what we are already familiar with and taking a fresh perspective on the future potential of our technologies."

Biomass opens up new opportunities for companies especially in the pulp and paper, sugar and biofuels, oil and gas, chemicals and power generation industries.

**Intensified use of wood**

Bio-refining is definitely nothing new for pulp and paper mills, since making pulp and paper out of forest resources is bio-refining at its purest. So what’s in it for the mills? In the short-term, new opportunities and revenues.
It is no secret that the pulp and paper industry is facing challenges in the modern electronic age. Mills are thus actively seeking new revenue streams and ways to maximize the value created from each processed ton of biomass.

"Valmet offers technologies for intensifying the use of wood and for using various waste flows. Our target is to convert biomass into renewable energy like producer gas and biofuels, lignin-based new products and nanocellulose, composites and bio-plastics, as well as new paper and board grades," Niemelä points out. "We are continuously introducing new tools and processes for our customers and thereby contributing to the development of new business opportunities."

Practical examples of new approaches include the structuring of tissue paper in Valmet’s novel NTT process, or making containerboards and cartonboards with less raw materials, or using multilayer curtain coating to produce specialty grades.

Innovations improve efficiency
Other key elements in bio-refining are cost efficiency and energy efficiency. Due to rising energy prices, all mills need to pay more attention to their energy consumption and operating costs. New innovations developed by Valmet are already making pulp and paper makers’ production processes more efficient. They include, for instance, a press to improve press dryness and save energy as well as a new process for low-consistency refining.

"We truly are committed to bio-refining and will develop new concepts and make them into winning solutions," Niemelä continues. "And our total offering is just the same as it is now in our traditional areas of business, ranging from new installations to rebuilds and services. For example, the importance of start-up services is likely to increase in this challenging area of new technologies."

In order to ensure that their targets are achieved, Valmet works in close partnership with customers who are looking for ways to improve the productivity and availability of their processes throughout the entire life cycle.
More fuel alternatives with Valmet’s Waste-to-Energy concept

When boosting sustainability and eco-efficient energy production, nothing of value should be wasted. To achieve this goal, Valmet offers sustainable solutions for optimum energy production from waste-derived fuels.

Non-recyclable waste can be a valuable fuel for energy production. For example, a city can use Valmet’s solutions to maximize its revenues from recycling materials and also from generating electric power, heating, and cooling.

"Valmet’s technology offers high fuel flexibility and an electrical efficiency that can be as high as in biomass-fired power plants. This gives the plant operator more options when choosing fuel and also generates more electricity. Both of these benefits greatly improve plant profitability," says Pertti Petänen, Director, Products and Technology, Valmet. "Our technology gives very efficient combustion, which results in extremely good environmental performance."

Whatever your needs, Valmet’s fluidized bed technology gets the job done

Valmet has long experience in combustion and gasification based on fluidized bed technology. Since the late 1970s, Valmet’s boilers and gasifiers have been used to combust various types of solid fuels, such as fossil fuels, biomass, and recovered fuels. Whether combusting wet biomass and other low-heating-value fuels or with high-heating-value fuels, the performance is excellent. In Valmet’s Circulating Fluid Bed waste-to-energy boilers, the high-temperature heat surfaces are protected from the corrosive substances in the flue gases. This gives high steam data and increased production of electricity.

Valmet builds fluidized bed boilers with a fuel input of up to 1,000 MW, and the biggest waste-fired plant combusts over 400,000 tonnes of waste per year. Valmet also delivers smaller plants. "For plants with a fuel consumption of some 100,000 tonnes per year, we have a modularized waste-to-energy solution that makes project development relatively easy. The plant produces approximately 9 MW of electricity," Petänen points out.

Valmet has also pioneered waste gasification. One of the biggest benefits of this technology is that electricity efficiency can be even higher than in traditional combustion.

Low emissions and stable operation

If a fuel is not completely combusted, the risk of emissions of hazardous compounds can be high. "In our fluidized bed boilers, the fuel is exposed to a high temperature and mixed very well with oxygen."
Combustion efficiency is excellent, with very low levels of unburned fuel in the ash and a low oxygen content in the flue gas," Petänen explains. "And the hot flue gas has a long retention time at high temperatures, which keeps emissions levels very low."

"Our fluidized bed boilers run well when fuel quality varies, and this helps to keep the reliability high," he continues. "Our boilers can also be run with varying loads, which in some circumstances can be very useful."

**Pre-treating waste can create a new market**

Combustion in fluidized bed boilers enables a high-efficiency recovery process that fulfills today's waste hierarchy targets.

Shredding and removing metals from waste are both essential parts of the recycling and recovering processes. In fact, this has created a new market for fuel preparation. Tighter quality control of the Solid Recovered Fuel (SRF) benefits other users, such as metal recycling companies, as well. Fuel suppliers will be able to invest in new machinery and create new jobs in the supply chain.

**Excellent results from challenging fuels**

Solid Recovered Fuel is one of the most challenging fuels because it typically contains a lot of chlorine, heavy metals, and incombustible debris. SRF often causes significant fouling, corrosion, and combined corrosion-erosion in the boiler.

Valmet has developed solutions that have proven to be suitable for demanding fuels, and good results have been achieved; for example, at the E.ON Händelöverket plant in Sweden (Figure 3). In 2002, Valmet built a circulating fluidized bed boiler that produces electrical power, process steam, and hot water for district heating. Up to 200,000 tonnes of waste per year is combusted and the fuel flexibility is high. The fuel mix is 30–50% combined household waste, 50–70% classified industrial waste. The boiler is designed for 65 bar (g) and 470°C with a capacity of 75 MWth, and a fuel input of about 83 MW.

Another example is the boiler at the Stora Enso Langerbrugge paper mill in Gent, Belgium (Figure 4). This is designed for 125 MWth (~137 MWfuel), 45 kg/s, 60 bar (g) and 475°C. The fuel (Figure 5) is Refuse Derived Fuel (RDF), untreated and treated wood, and coal with a heating value range of 10–26 MJ/kg. Fuel flexibility is high here as well, and all fuels can be burned separately with a 100% energy share. The overall boiler availability and reliability have been very high; the latter is about 99%.
Currently, Valmet is delivering the world’s largest recovered fuel-fired boiler to Mälarenergi in Sweden. The boiler will be commissioned in the spring of 2014 and is designed to burn up to 70% household waste and up to 100% industrial waste. In addition, sludge, recovered wood, peat, and biomass are part of the design fuel palette. The boiler is designed for 155 MWth, 58 kg/s, 73 bar (g), and 470°C.

**Gasification – a new, high energy-efficiency conversion technology**

The main benefit of waste gasification, compared to other waste-to-energy processes, is the higher electrical efficiency that gasification offers.

In Valmet’s waste gasifier, waste-derived fuels are gasified into combustible product gas, which is cooled, filtered, and then combusted. The filtration removes the corrosive components from the gas so it can be combusted in a boiler with high steam parameters. This enables a higher production of electricity compared to traditional combustion.

In the spring of 2012, a 160 MW power plant based on Valmet’s gasification technology was started up in Lahti, Finland. The Lahti gasification plant is the largest and most efficient waste gasification power plant in the world. It processes 250,000 tonnes of SRF per year and produces 50 MW of electricity and 90 MW of district heat. In addition to SRF, the plant has been operating successfully with logging residue (up to 45% water content) and plastic-rich waste (18% water content). The experiences from the first year of operation have proven both the technology and cost structure to be viable for large-scale power generation.

"The key results in Lahti include high electrical efficiency achieved from waste-to-energy as well as a major reduction of fossil fuels and CO₂ emissions," Petänen comments.

**Strong R&D and solid experience - the foundation of technology**

Today, Valmet is a forerunner in the development of fluidized bed technology. Valmet’s main focus over the last 15 years has been on the utilization of renewable fuels and opportunity fuels. Valmet’s Research Center in Tampere, Finland, provides excellent possibilities to test new fuels. The center has three test reactors for fuel testing.

Since 1979, Metso, now Valmet, has supplied more than 300 boilers featuring fluidized bed technology. During the past ten years alone, the company has delivered more than 13 GWth of boiler capacity that utilizes renewable fuels. "This is a significant contribution to lower CO₂ emissions. Our solutions really help our customers make a difference," Pertti Petänen concludes.
A coal-fired plant goes green

The world’s largest biomass gasification plant came on stream in March 2013 at Vaskiluodon Voima Oy in Vaasa, Finland (Figure 7). With Valmet’s technology in place, close to half of the coal used by the plant can be replaced with gasified biomass, contributing to a massive reduction of CO₂ emissions.

The new 140 MW biomass gasification plant (Figure 8) features Valmet’s innovative concept for gasifying and utilizing biomass. The delivery included fuel handling, a large-scale dryer, and a circulating fluidized bed gasifier, modification work on the existing coal boiler, and an automation system. The bio-gasification plant was constructed as part of the existing coal-fired power plant, and the produced gas will be combusted along with coal in the existing coal boiler.

The plant is groundbreaking in many ways, particularly as this is the first time anywhere in the world that biomass gasification is being adopted on such a large scale for the replacement of fossil fuels.

"Vaskiluodon Voima made a coal-fired plant go green, and for this reason will set an example for others to follow in the future," explained Jyrki Holmala, President of Valmet’s Power business line.

Close to half of the coal used by the plant can be replaced with gasified biomass. This means the solution is highly environmentally friendly, it also enables the flexible use of different fuels and significantly extends the life of the current power plant.

"We now use three to six kilos less coal per second in our production than earlier. This means having one coal shipment less per month," explains Matti Loukonen, Power Plant Manager of Vaskiluodon Voima.

Valmet’s work safety is highly valued

Loukonen is happy that the project is now finally completed and everything went according to plan. Special thanks must go to Valmet’s work safety culture. "Although at some point there were about 200 people working on the site, there was only one incident reported—and that was a strain injury!"

Mauri Blomberg, Managing Director of Vaskiluodon Voima, is happy that the company now has an alternative to coal-firing in its processes.

"I’m sure that gasification is the right choice for us, and I believe that other power plants will also start to use it," he commented. "Valmet is our long-time partner and was thus a natural choice to supply the technology."
Bio-oil production offers an extra revenue source for CHP plant

With integrated pyrolysis technology, a fluidized bed boiler at a power plant can be turned into a bio-refinery that offers new business potential. To this end, Fortum is building the world’s first industrial-scale integrated bio-oil plant in Joensuu, Finland (Figure 9).

The brown liquid in a little bottle on the table smells like the tar that was produced hundreds of years ago from the wood and roots of pine by destructive distillation under pyrolysis. It was mainly used for preserving wooden vessels against rot. However, the liquid in this bottle is actually bio-oil, which was only recently produced under integrated fast pyrolysis.

Pyrolysis means decomposition of fuel in an oxygen-free environment by heat. In our modern context, fast pyrolysis produces bio-oil that can be used as such to substitute, for example, heavy fuel oil. Wood-based biomasses are well suited as raw material for bio-oil.

"An integrated pyrolysis process is linked with a commercial-scale fluidized bed boiler, either a circulating or a bubbling fluidized boiler. The hot boiler bed material is used as the heat source," points out Joakim Autio, Product Manager, Pyrolysis, at Valmet’s Power business line.

Excellent energy efficiency

The pyrolysis process sets strict requirements for wood-based biomass. It needs to be very dry, and its particle size must be under the 5 mm size limit. This solid biomass is heated up in a reactor (pyrolyzer) to approximately 500°C in just a few seconds. At this temperature, the biomass is vaporized into gases, which are then condensed into a liquid form, i.e. bio-oil, when cooled. The uncondensed gases and coke generated during pyrolysis are combusted in the boiler as fuel.

One of the many benefits of an integrated bio-oil plant is its excellent energy efficiency. The bio-oil production process can utilize heat that the power plant would not otherwise utilize—for example, in the energy-intensive drying process.

"Power plants will be able to optimize their production with regard to electricity, heat, and bio-oil. As the same staff can operate all the processes, there are also synergy benefits in this sense," Autio adds.

Four strong partners sharing expertise

The concept took years to develop, but the project actually proceeded rapidly considering all the new aspects and challenges involved. In 2007, Metso (now Valmet), UPM, and VTT Technical Research
Centre of Finland started to work on a biomass-based bio-oil production concept based on integrated fast pyrolysis.
The target was to provide an alternative to fossil fuels and thus reduce the burden on the atmosphere. The fourth partner in the consortium, Fortum, joined the development project in 2009.

"Valmet has delivered hundreds of fluidized bed boilers worldwide, so we see potential in expanding towards bio-oil production with integrated pyrolysis technology," Autio explains. "In the project, we have been in charge of the technological development of the pyrolysis process integrated into the fluidized bed boiler."

The forest products company UPM has added to the project's expertise in the use of biomass as a raw material. The company's target is to utilize all parts of a tree in the process in order to produce liquid fuels in a cost-effective way. Fortum has brought the perspective of an energy producer and end-product user to the project. The company's long-term goal is to avoid all carbon dioxide emissions in its production.

The bio-oil production process is based on VTT's earlier research and patents, and VTT's researchers and specialists have contributed strongly to the success through their in-depth know-how and expertise.

**The world's first integrated plant is progressing in Joensuu**
The development work reached a high point with the first commercial-scale deal—signed with Fortum in March 2012. The integrated bio-oil plant, the first of its kind in the world on an industrial scale and based on fast pyrolysis technology, was recently commissioned at Fortum's CHP plant in Joensuu, with the foundation stone having been laid in November 2012.

"A plant such as this one, integrated with the existing electricity and heating plant, is unique in the world. Soon we will have the world’s first combi-plant, generating electricity, heat and bio-oil," said Timo Partanen, Fortum's Regional Director for eastern Finland, speaking at the foundation stone ceremony.

The opportunities provided by the integrated pyrolysis process lie not only in replacing heavy fuel oil at power plants. There are scenarios that bio-oil could also be used as raw material for bio-chemical and biodiesel production in the future.

"The demonstration of pyrolysis technology is also an indication of our company’s strategy of offering energy solutions in which technologies related to fuel refining have been brought about alongside traditional combustion. Naturally, we are commercializing our pyrolysis technology globally, and
reference plants such as the one in Joensuu will be extremely valuable in our future success,” said Jyrki Holmala, President, Valmet Power business line, in his speech at the ceremony.

The nominal output of the Joensuu bio-oil plant is 30 MW of oil production, and the planned annual production is 50,000 tonnes, which corresponds to the yearly heating consumption of more than 10,000 private houses. The new bio-oil production plant was started up in late 2013.

**Emissions to be reduced by 70%**

The integrated fast pyrolysis process has been identified in several studies as an economically viable liquid biofuel concept to reduce CO₂ emissions. According to such studies, the use of bio-oil has a significant positive environmental impact because energy produced with bio-oil reduces greenhouse emissions by more than 70% compared with fossil fuels.

The integration of bio-oil production into the power plant process enables the utilization of the by-product from the production process in the generation of electricity and district heating. The utilization of bio-oil produced at the Joensuu plant helps reduce carbon dioxide emissions by 59,000 tonnes and sulphur dioxide emissions by 320 tonnes per year.

**Valmet meets the demand for Bioethanol plants and green coal with experience and new technology**

Today the focus in the emerging bio-refinery area is in second-generation biofuel for the transport sector; other end products will become interesting as the industry matures.

Bioethanol plants are operated in various forms, they can be anything from companies in the chemical and oil industries to forestry companies facing the fact that the demand for some of the traditional products is decreasing. The challenge is to find new revenue sources. For example, using residues from the forest to produce various forms of biofuels or other useful and marketable products has proven successful.

"Valmet’s focus is on second-generation biofuels, primarily ethanol. Green coal is also a priority as this product will reduce CO₂ emissions significantly in the future. Green coal can primarily be used as a carbon-neutral and environment-friendly fuel in power plants to replace up to 45% of the fossil coal. During the past year, Valmet has been in contact with over 70 companies interested in building pilot, demonstration or commercial-scale bio-refinery plants. This has already resulted in nineteen systems sold”, says Rickard Andersson, Vice President, Bio Business Development, Fiber business line.

**The driving force for developing biorefineries and three main routes**

"Valmet is developing processes and equipment in three main routes where the end products are second-generation bio-based transportation fuels, chemicals and materials via concentrated acid hydrolysis of biomass and green coal. Today our technology is mainly suitable for the initial steps of the process chain: pretreatment and feeding of biomass into pressurized reactors, separation of liquids and solid reaction products, and separation and recovery of steam”, says Andersson. The solutions develop all the time to include more sub-processes in the bio-refinery chain, through co-operation with customers and development work.
The key driving force for producing transportation fuels from biomass and green coal is to reduce global warming through reduced emissions of fossil carbon dioxide. The production of chemicals and materials, e.g., polymers and plastics from biomass, contributes to making the society more sustainable. A finite resource – fossil oil – is replaced by renewable biomass. Moreover, several countries would like to reduce their dependence on fuel imports.

**Valmet has proven technology for annual fibers and forest products**

Most of the potential bio-refinery projects are looking at agricultural and forest industry residues as feed stock. "Valmet has experience and proven technology for annual fibers and forest products and can mainly supply equipment to the front end of a bio-refinery", says Andersson.

There are several process solutions, but the hydrolysis stage will be a key first process unit for all variants. C5 (xylose) and C6 (glucose) sugars will be the key intermediates. From these, not only ethanol can be produced, but also many chemicals that will be important as the industry develops.

**Refining of biomasses to green coal**

Three different methods are available for refining of biomasses to green coal. Torrefaction is a process where biomass is heated without oxygen, breaking its fibrous structure, removing vapors and volatiles, and giving it coal-like physical properties. Hydro Thermal Carbonization (HTC) method is torrefaction in liquid phase and takes place in a pressurized reactor. Steam Explosion (SE) is a method where the biomass is heated with steam in a pressure vessel and then blown to atmospheric pressure breaking the material structure.

Valmet primarily uses the steam explosion method as pellets produced by this method have many good physical properties. For example, the quality is high, it is water resistant and the manufacturing process maintains a high level of security. Valmet already has the technology required and successful pilot trials have been conducted.

**Breaking ground into a new market**

In July 2012, Clariant, the Swiss specialty chemicals company, inaugurated Germany’s largest second-generation bioethanol plant. With an annual production of 1,000 tonnes, the plant will produce climate-friendly cellulosic ethanol from around 4,500 tonnes of agricultural waste, such as wheat straw. The pretreatment system in the plant is supplied by Valmet. This project is a good example of Valmet breaking ground into a new market with proven and improved technology, while at the same time reducing the environmental impact. Tests were done in Valmet’s Sundsvall pilot plant and the result was a really good end product after the pretreatment stage. The biofuel produced at Clariant (second-generation bioethanol), cuts CO₂ emissions by about 95% compared to fossil-based fuels without competing with food production. There is no "food or fuel" issue as plant waste is recycled. "This plant clearly demonstrates that products traditionally based on petroleum can be manufactured to the same standard
using biomass. Thus this new plant serves as an important contribution to a sustainable Bio-Economy”, the Federal Minister of Research of Germany, Annette Schavan said during the inauguration.

**Strong demand in the future**

If the established national climate targets for the share of bio-based transportation fuels by 2020 would be met exclusively by second-generation bioethanol, it would require 130 billion liters. This volume will not be achieved. A more reasonable estimate, made by McKinsey, is 25 billion liters of bioethanol from lingo-cellulosic materials by 2020. The announced demand would require building more than 300 second-generation bioethanol plants based on cellulose within the next ten years. Building that many plants may not be possible, but the demand will grow, the market is there and the driving forces will increase. Emissions from power producers in the EU have been regulated by a directive which comes into force in 2016. The limit values for nitrogen and sulfur oxides and particulates are thereby tightened, making it beneficial for power plants to replace hard coal with biomass in the near future.

**Conclusions**

Valmet has begun the next generation of bio-technology; using what was once considered waste to produce new revenue streams and create a more sustainable future.

Valmet is investing in its growing bio organization to cope with pressure from the market. The company has many products suitable for second-generation bioethanol and pellets plants. The possibilities are many and the demand is strong. Valmet will meet it with experience and new technologies.

*This white paper combines technical information obtained from Valmet personnel and published Valmet articles and papers.*

*Valmet provides competitive technologies and services to the pulp, energy and paper industries. Valmet’s pulp, paper and power professionals specialize in processes, machinery, equipment, services, paper machine clothing and filter fabrics. Our offering and experience cover the entire process life cycle including new production lines, rebuilds and services.*

*We are committed to moving our customers' performance forward.*