Bioenergy production and monitoring

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Contents

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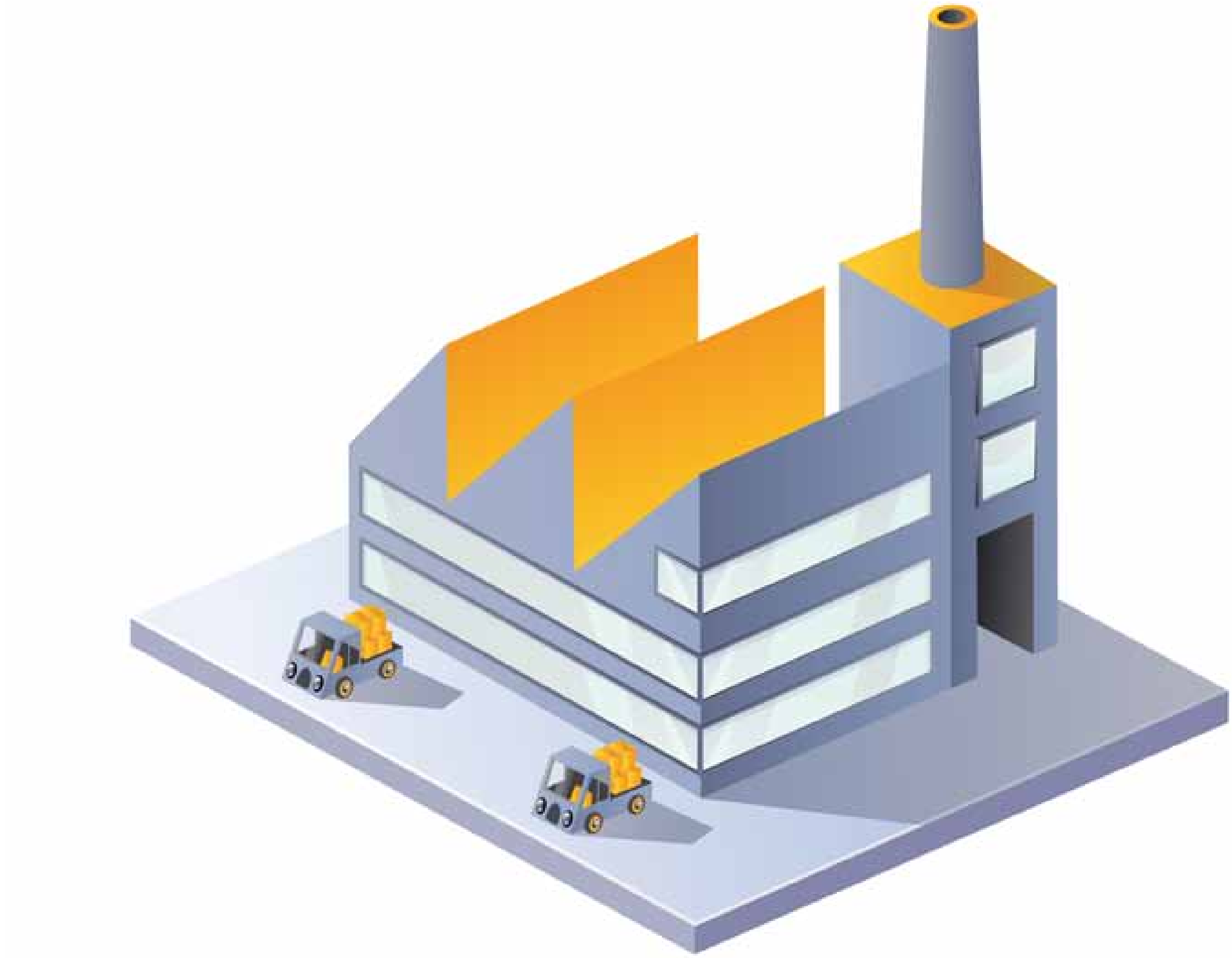

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Bioenergy, produced by biomass and biogas combustion, is the world's most common form of renewable energy production. It is a carbon-fuel energy source, but the difference when compared to coal and natural gas is that the fuel is captured from the Earth's biosphere, making it a carbon-neutral process if the fuel is supplied from a renewable source. Like coal-fired power generation, however, the efficiency of the process needs to be monitored, as well as the range of toxic materials that can be released when burning organic materials and other waste.

In Australia, the use of bioenergy is relatively low compared to other parts of the world – but done correctly, with the right fuel sources and management, there is no reason it cannot take on a greater role in supporting our future energy needs.

Glenn Johnson

Editor - *What's New in Process Technology*

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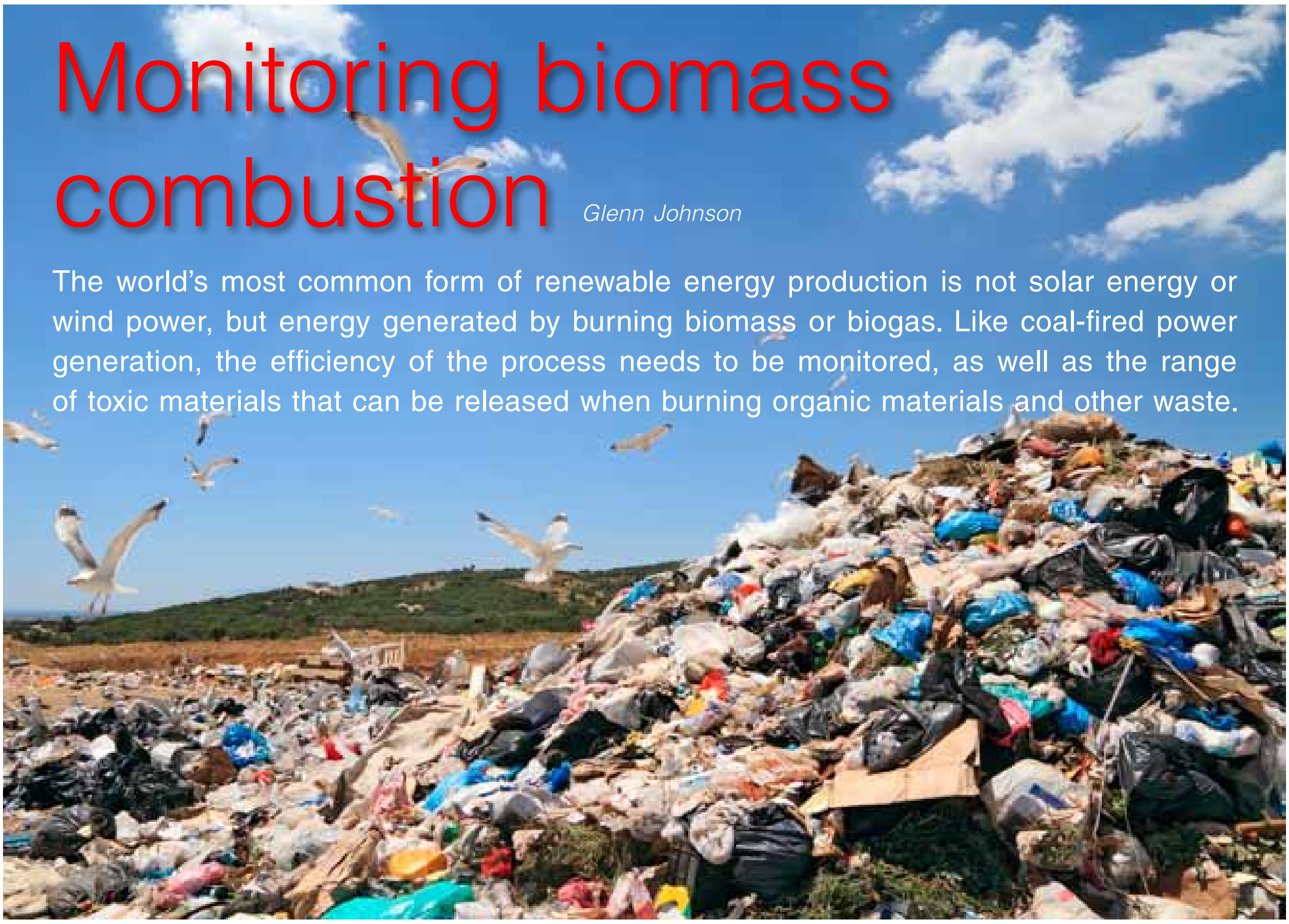
Monitoring biomass combustion

Glenn Johnson

The world's most common form of renewable energy production is not solar energy or wind power, but energy generated by burning biomass or biogas. Like coal-fired power generation, the efficiency of the process needs to be monitored, as well as the range of toxic materials that can be released when burning organic materials and other waste.



In a general sense, bioenergy is a form of renewable energy derived from biomass, which is used to generate electricity and heat or to produce liquid fuels. Biomass is any organic matter of recently living plant or animal origin, and is available in many forms such as agricultural products, forestry products, and municipal and other waste.

Bioenergy technologies make up a significant proportion of renewable energy production around the world. For example, the US Institute for Energy Research[1] reports that approximately 5.2% of energy is generated from biomass, accounting for 55% of renewable sources. In Australia this is considerably less, with the Australian Renewable Energy Agency (ARENA)[2] reporting that bioenergy sources account for approximately 1% of electricity generation and about 7% of renewable sources. According to ARENA:

"Australia's bioenergy industry currently uses a range of biomass resources including:

- *bagasse, which remains after sugar has been extracted from sugarcane*
- *landfill gas*
- *wood waste and black liquor*
- *energy crops*
- *agricultural products*
- *municipal solid waste.*

The majority of Australia's installed bioenergy capacity is derived from bagasse cogeneration."

Although the burning of biomass releases carbon into the atmosphere in the same way that coal-fired power generation does, the difference is that the fuel is captured from the Earth's biosphere. That is, the material being burned releases carbon that was only recently captured from the atmosphere, and so is a carbon-neutral cycle – in contrast with coal and natural gas, in which the carbon being released was trapped underground for many millions of years and is no longer a natural part of the Earth's biosphere.

As carbon-neutral as biomass generation may be, however, there are still challenges associated with other toxic compounds that are released during the burning of the fuel, requiring the same type of careful measurement and monitoring as other processes.

Challenges

There are number of challenges associated with the transformation of biomass into electricity. Firstly, the efficient use of fuel and the protection of assets are of utmost importance to ensure optimum profitability; secondly, emission monitoring and pollution control is a requirement in nearly every country. It is imperative for every industrial plant to monitor the production process from material flow to pollution control and to maximise energy efficiency – but with minimal danger to the plant staff or damage to the environment. To achieve these goals, there are important monitoring requirements for:

- fuel flow to the burner for custody transfer and boiler efficiency monitoring
- the efficiency of the pollution removal system – for pollutants such as dust or gas (SO_2, NO_x, etc)
- bulk material transport and storage monitoring – measuring the level and volume flow of the fuel.

Biogas

Biogas typically refers to a mixture of gases resulting from the breakdown of organic matter in the absence of oxygen, and can be produced from raw biomass materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.

Biogas can be produced as landfill gas, by anaerobic digestion (in which anaerobic bacteria are used to digest material inside a closed system) or by fermentation of biodegradable materials. Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. The gases methane, hydrogen and carbon monoxide (CO) can be combusted or oxidised with oxygen, allowing biogas to be used as a fuel.

Process monitoring

Fuel storage and delivery

Solid biomass is generally stored in silos until it is ready to be used as fuel. Such silos require some form of level monitoring for quantifying the fuel supply and for overfill prevention.

Conveyors are used to transfer solid biomass to shredders, and from the shredders to the incinerators. In order to monitor fuel use, and to measure the efficiency of the plant, the volume of material being moved needs to be measured. Conveyor mass flow is often measured by continuous weighing, but this can result in significant inaccuracies in this application as on rainy days, the biomass absorbs a significant amount of water and becomes heavier. A better method is to use a laser scanner to measure the material volume.

In the case of biogas, an ultrasonic flow meter can be used to measure the volumetric flow rate.

The raw fuel storage also needs protection from combustion in the silos and shredders. For this purpose, a gas analyser that simultaneously measures O_2 and CO can be used to detect smouldering fires in the material.

Incinerator optimisation

Incineration requires O_2, and measurement of the O_2 concentration at the outlet of the combustion chamber allows the oxygen concentration to be optimised to maximise the burner's efficiency.

Denitrification systems

The reduction of NO_x emissions is performed by two methods: non-catalytic and catalytic reduction.

In non-catalytic reduction, an ammonia (NH_3) or urea solution is injected into the combustion process at 900-1100°C. The compound reacts with the nitrogen oxides to produce nitrogen and water. It is therefore necessary to measure the NO concentration at the combustion chamber outlet, as well as unreacted NH_3.

Catalytic reduction involves the removal of nitrogen oxides from flue gases with the injection of ammonia along with a catalyst at 200-400°C. As for non-catalytic reduction, the NO concentration after reduction, as well as unreacted NH_3, need to be measured.

Measurement of NO and NH_3 are performed with a gas analyser suitable for measurement of nitrogen compounds. For compliance with emission regulations, these compounds also need to be detected and measured in the final flue gas output.

Flue gas scrubbers

Flue gas scrubbers are used to remove further toxic compounds: hydrochloric acid (HCl), sulfur dioxide (SO_2) and mercury (Hg and $HgCl_2$).

Wet scrubbers spray a cleaning solution into the output gas, while dry scrubbers use lime powder or milk of lime. To remove heavy metals and organic pollutants, activated carbon is also added. To optimise the consumption of the reagents and to monitor the scrubbing effectiveness, a gas analyser is needed that can simultaneously measure SO_2, HCl, water and, optionally, O_2.

Mercury can be released when incinerating waste. If the Hg concentration is very high (greater than 3000 μg/m^3), action needs to be taken to ensure that the emission thresholds are respected.

Dedusting

The flue gas is dedusted to remove particulates using electrostatic precipitators and fabric filters. The filters also separate bicarbonate and activated carbon left over from the scrubbing process.

Dust concentration is most effectively monitored using a laser scattering instrument. The particulates also need to be measured in this way in the final exhaust stack for compliance purposes.

The dust particles that are filtered out are collected in an ash hopper. To determine when the hopper is full, a vibrating fork level switch can be the most effective method for detecting when the hopper is full.

Emission measurement

For environmental compliance, the final output from the stack needs to be monitored. Depending on the type of fuel, the following pollutants will need to be detected:

- HCl, HF, CO, NO_x, SO_2 and NH_3
- Total organic carbon
- Dust
- Gas velocity, pressure, temperature, O_2 and H_2O

In some countries, continuous measurement of mercury content is also required.

The gaseous components can be measured using direct in-situ or sample extraction methods. The pressure and temperature parameters are measured for normalising the gas sample measurements.

The dust component can be measured using an instrument that uses a laser light scattering method.

If HF or Hg detection is required, instruments specially designed for the purpose are readily available.

Other measurements

As consumables, the supply of reagents and activated carbon also need to be monitored. For these purposes, overfill protection can be afforded using a vibrating fork level switch, both for solid and liquid reagents.

As for solid fuel silos, activated carbon filter beds need to be monitored to be sure that fires do not occur - usually with a twin-component multigas analyser that can measure changes in CO concentration.

Conclusion

Similar to coal-fired power generation, biomass and biogas power generation requires significant monitoring and offers a good example of what can be measured and what benefits can be derived through investment in the right probes and sensors. Through direct real-time measurement, renewable power generation plants can be accurately monitored for plant efficiency, fuel and reagent consumption and emission monitoring.

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2 http://arena.gov.au/about-renewable-energy/bioenergy/

Biogas cogeneration

The path towards climate-smart farming and agriculture

Athena Dennis

World Bank Special Envoy for Climate Change Rachel Kyte delivered a worrying message at a Canberra conference, stating, "Global agriculture requires a radical shift akin to a military about-face sooner than most people realise, in order to feed an exploding population while preventing dire social and environmental outcomes."

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According to Kyte, cereal yields will decline by 15-20% if current agricultural practices continue in the next three decades. In order to feed the global population of 9 billion people by 2050 with nutritious food, there needs to be fundamental shift in how we grow food and limit carbon emissions.

Recent research cited by World Bank shows that agriculture and land use changes are directly responsible for 30% of the world's greenhouse gas emissions.

Fast facts about food consumption and carbon emissions

- Meat consumption in emerging economies of the world is expected to grow 75% between 2005 and 2050. This will increase to 30 kg per person, per year; this intensifies pressure on crop lands and generates higher carbon emissions.
- For every 1 kg of meat consumed, an additional 10 kg of feed is required.
- A recent CGIAR-funded study found that beef and dairy cattle account for up to 77% of global greenhouse gas emissions from livestock.

Climate-smart farming and agriculture: a paradigm shift

Unless we figure out new methods of food production, legislation and resource management, the world will face disruption to food sources - not 30 years from now, but possibly within the next decade.

Treading water to stay in the same position isn't really an option. New and intelligent solutions are required to galvanise industry, government and consumers to work as one in order to better manage agricultural resources. Innovative solutions are required to feed the growing population of the world and also to protect the planet.

Climate-smart agriculture means providing an integrated and broad approach to food that factors in areas like sustainability, carbon emissions, climate change and nutrition. The answer to this issue doesn't need to be a trade-off; instead, it can be a three-fold win for the natural environment, consumers and business: biogas cogeneration for agribusiness.

Biogas cogeneration: how it works

Biogas cogeneration is suitable for use in food processing facilities, livestock and dairy farms, agribusinesses and also food waste and treatment facilities. This technology is capable of up to 90% energy efficiency, resulting in far lower carbon emissions per tonne of food produced.

This sort of technology offers a win-win for agriculture and the sustainable energy sector. It provides the same food production levels while also mitigating against carbon emissions and therefore climate change.

According to a study by the Australian Meat Processor Corporation, biogas cogeneration is the most economical renewable energy source - especially for labour-intensive tasks like on-site meat rendering, which take up to 70% of the heat energy at the facility. Typical payback scenarios range between 3.8 and 10.1 years.

What this means for farms and agricultural businesses is that they can have an efficient and decentralised source of energy and produce food for a lower cost. At the same time, these businesses manage their energy consumption efficiently with a decentralised power source that uses waste products to generate energy to run the farm.

This method of power generation is at least 40% more efficient compared to ultrahigh-efficient micro-turbines. Biogas cogeneration is a prime example of how food production can still operate within a sustainable environmental framework.

The way forward

Evo Energy Technologies has combined its solid industry reputation in Australia for energy-efficient products with 2G's track record of thousands of biogas CHP plants successfully installed in facilities all over the world.

First the company conducts a rigorous feasibility study to evaluate project risk, operational output, budget and all other variables. This means that all of the hard work is already done for feasibility by skilled project managers.

Right from the beginning, EvoET provides end-to-end energy solutions that are clear about service deliverables, the ROI scenario and pricing structure.

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Bioenergy:
Australia's forgotten renewable energy source (so far)

Mark Brown, University of the Sunshine Coast
Annette Cowie, The Conversation

When we think of renewable energy, it's easy to picture spinning wind turbines or rooftop solar panels. But what about bioenergy?

While wind and solar are now well established – in South Australia wind now supplies 33% of the state's power generation, while nationwide there are more than 1.3 million roofs now sporting solar panels – bioenergy has nowhere near the same reach or profile in Australia as it does in many other parts of the world.

Modern bioenergy is not simply about burning wood to provide heat, or using crop-based oils, sugars and starches for ethanol and biodiesel. The range of available biomass sources now includes municipal waste, forest slash, invasive weeds and cereal straw, and they are being used to make products like biogas, green electricity and jet fuel.

CSIRO research has previously shown that bioenergy could contribute substantially both to Australia's electricity generation (up to 20% in 2030), and to its liquid fuel needs (30-40% by 2020). If used at this scale, emissions in both of these sectors would drop significantly.

Slow out of the blocks

There are many reasons why bioenergy's huge potential has not yet been realised: economics, sustainability concerns, logistics, the bewildering array of options, and investors' wariness of new technologies.

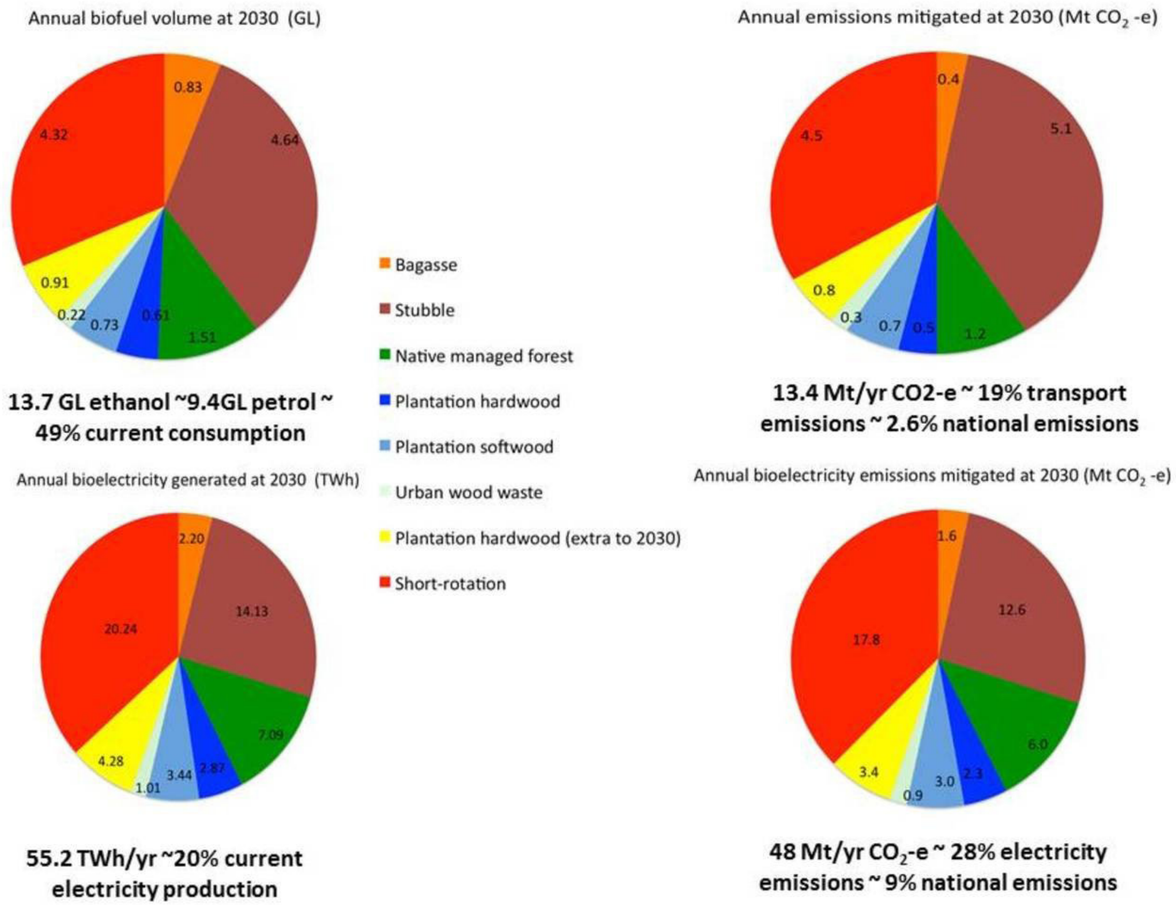
From one perspective, different renewable energies like wind, solar and bioenergy are in competition with each other and need to be compared on the basis of their economic, environmental and social implications. If the full suite of new energy technology is added to the equation, this comparison becomes even more complex.

Yet recent research has shown that rather than being competing alternatives, different renewable energy solutions could complement one another. One example is hybrid bioenergy-solar systems, in which the solar output is supported by biomass burning, making the energy generation process more efficient and reducing the need for the solar energy to be stored in order to smooth out supply.

On top of the uncertainty about all these possible permutations, there are also the usual business and investment concerns around new technology in new markets. Add them together and you start to see why progress can be slow without clear policy support.

In the transport sector, bioenergy could help reduce fossil fuel use in areas that, for logistical reasons, can't embrace existing sustainable options such as electric vehicles. Aviation, agriculture, mining and shipping will all have to rely on liquid fuels in the short-to-medium term, and biofuels could offer an alternative that has lower in carbon impacts and particulate pollution.

New technologies mean that these fuels can now be made from non-food sources such as wood and straw. These fuels are not complementary liquids like ethanol which can be used in "blends"; rather, they are functionally equivalent fuels which are indistinguishable from fossil counterparts.



Possible contributions of bioenergy to Australia's transport and electricity sectors in 2030. Farine et al.

These fuels can be used as straight replacements for diesel, petrol and even aviation fuel. The global aviation industry including such companies as Airbus, Boeing and Virgin Airlines have been developing and trialling these fuels, and some of them already meet the very high requirements for performance and safety in aircraft.

Biomass burning is big elsewhere

In contrast to the limited recognition of bioenergy in Australia, biomass is playing a key role in meeting the European Union's sustainable energy targets, and in providing energy independence to the US military in terms of both electricity and liquid fuels.

Bioenergy offers opportunities not just for improved fuel self-sufficiency and emissions reductions, but also offers regional benefits of jobs, small business opportunities, diversification of incomes and risk management for farmers, and landscape renewal through actively managing the woody resources needed to make the fuels.

The question for Australia is: how can we take advantage of these opportunities? The Renewable Energy Target (RET) scheme creates a mandate for uptake of sustainable energy in the electricity sector, with its target of 41 gigawatt hours of power from renewable sources in 2020.

The RET has been very effective in stimulating rapid expansion of generating capacity, especially wind. But there has been little uptake of bioenergy, and the current uncertainty over the scheme's future could reduce these prospects still further.

Australia needs to invest in demonstration and development of the most promising bioenergy options and their supply chains, to accelerate the learning curve and drive down costs. It is critical that the RET be maintained, as this provides the certainty to business that allows investment. Ideally the RET should also be accompanied by a comprehensive climate change policy that drives improvements in energy efficiency.

Should bioenergy (and other renewables) receive such support, or should they instead be expected to stand or fall on their own economic merits? Groups like the Climate Institute have recently attempted to quantify the direct and indirect financial support that the very mature and established fossil energy industry continues to receive from the government.

In contrast, the emerging bioenergy industry does not receive the same level of support. For more than a decade, government policies have acted to reduce the limited financial resources available for this sector.

Improved support for research and development, and a more level playing field for renewable fuels in comparison with fossil fuels, would go a long way towards allowing Australia to join much of the rest of the world in benefiting from bioenergy.

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Söderenergi in Sweden

Not only is the Igelsta plant one of Sweden's largest biomass power plants – the plant also received recognition as the 'Building of the Year' in 2009. It produces green energy for 100,000 homes and district heating for 50,000 homes. Measurement technology from SICK monitors the emissions.

"When the sun vanishes behind the clouds, we see energy demand shoot up," said Peter Hillblom, a mechanical engineer at the Igelsta plant in Södertälje. "We use measuring technology from SICK – the MCS100FT CEMS solution and also the DUSTHUNTER FWE200 scattered light dust measuring device for wet gases – to monitor our emissions, ensuring that they always fall within legal limits. Our aim is to keep improving."

In order to meet power and heat generation requirements, the power plant requires approximately 17,000 tonnes of fuel every week. The fuels used are mainly derived from forestry waste, such as chopped up wood from trees, supplemented by fuels derived from non-recyclable waste from the local area, such as waste wood, plastic and paper.

High-energy fuels for the 'St Martin's Goose' turbine

The steam produced through this combustion process is used to heat water for district heating and also to power the 'St Martin's Goose' steam turbine. The turbine was commissioned on St Martin's Day in 2009 and takes its name from the meal traditionally eaten at this time of feasting. Nevertheless, the powerful red turbine looks more like an organic monster than a high-tech creation. In the middle of the plant, the turbine is driven by high-pressure steam at a temperature of 540°C. This in turn powers an enormous generator which supplies 11 kV and 85 MW of power – enough to light up over 1.4 million 60 W light bulbs.

Söderenergi – a pioneer in the use of secondary fuels

Coal was the fuel used in the first Igelsta plant back in 1982. Social changes and the introduction of a CO_2 tax brought about a change: "We were very quick to start cutting down on fossil fuels and were soon able to switch to biomass and recycled raw materials. Our CO_2 emissions fell by 80%," explained Madeleine Engfeldt-Julin, communications manager at Söderenergi.

"We can consider ourselves successful pioneers in the use of secondary fuels. Our highly developed gas cleaning system means that the emissions coming out of our chimneys are almost exclusively steam," she added. "Not only is the number of pollutants very low now, Söderenergi is also constantly developing and refining its use of biological and recycled fuels."

The first company in Sweden to use SICK's FTIR measuring technology

In 2009 Söderenergi became the first company in Sweden to measure emissions using the new MCS100FT CEMS solution, which is based on FTIR technology (Fourier transform infrared spectroscopy). The system measures HF, HCI, NH_3, H_2O, CH_4, SO_2, N_2O, CO, NO, NO_2, CO_2 and O_2. As an option, it can also determine both NOx and VOC/THC concentrations. Research proves that the gas analysis systems deliver results with a consistently high measurement accuracy for up to 14 components used together in the same system.

The DUSTHUNTER FWE200 scattered light dust measuring device from SICK uses an extractive dust measuring system to determine particle emissions at temperatures below 100°C (below the acid dew point of the exhaust emissions). The SICK measuring systems are part of a monitoring and IT network which allows various measurement points within the plant to be remote controlled. This has one distinct advantage for Hillblom: "I can access the same images as the IT staff in the control room without having to go there myself."

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