Opportunities for Bioenergy in Australia

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Abstract

This paper profiles biomass as a source of sustainable energy. It illustrates the scale and scope of bioenergy world wide and the range of biomass resources that can be converted to heat, power, fuels and other value-added products. It notes the emergence of wood pellets as a renewable fuel. The paper takes a look at greenhouse gas emissions of bioenergy systems and compares these to several other energy sources. Energy conversion processes and technologies are examined and illustrated by examples of wood fuelled bioenergy plants. Emerging technologies examined are biomass gasification and the production and use of pyrolysis bio-oil. Bioenergy can provide several co-values and co-products and these are briefly covered, together with the various environmental and social values bioenergy can provide. The paper concludes by providing a brief summary of the Australian bioenergy industry.

Introduction

Biomass refers to organic matter, derived in recent times, directly or indirectly, from plants, as a result of photosynthesis. It includes a wide variety of materials, from forestry and agricultural residues, to organic waste by-products from various industries, purpose grown energy crops, to woody weeds and municipal green waste. Bioenergy is the term used to describe energy and energy related products derived from biomass.

Bioenergy can be regarded as a form of solar energy, as photosynthesis combines atmospheric carbon dioxide with water in the presence of sunlight to form the biomass, while also producing oxygen. This process can be represented by the formula:

$$CO_2 + 2H_2O \xrightarrow[\text{Heat}]{\text{Light}} ([CH_2O] + H_2O) + O_2$$

where $[CH_2O]$ represents the biomass (as carbohydrates).

The energy bound into the biomass can be recovered through a variety of bioenergy processes and technologies. During the energy recovery process, the carbon dioxide bound in the biomass is released to the atmosphere. Bioenergy is regarded as renewable, when the biomass resource consumed in the energy conversion process is replenished by the growth of an equivalent amount of biomass. Globally some 220 billion dry tonnes of biomass are produced through photosynthesis per year. The energy stored globally in biomass represents about 0.02% of solar energy incident on earth. This small portion of the energy absorbed by biomass is equivalent to approximately eight times the global anthropogenic primary energy consumption of around 400EJ/year.

Biomass can present itself in many forms, from relatively dry (e.g. rice husks) to very wet (sewage can contain 98 percent water). As such, appropriate technologies are required to convert the biomass to the desired end products. Converting the biomass can utilise a variety of paths and technologies. The primary conversion processes are via thermal, biochemical or mechanical/physical processing. These are illustrated in Figure 1.

Bioenergy has an inherent advantage over other forms of renewable energy such as wind and solar energy. As the energy bound into the biomass provides inherent energy storage, bioelectricity can be dispatched, providing firm capacity, unlike some other sources dispatched by nature. This allows excellent utilisation of the bioenergy plant's capacity.

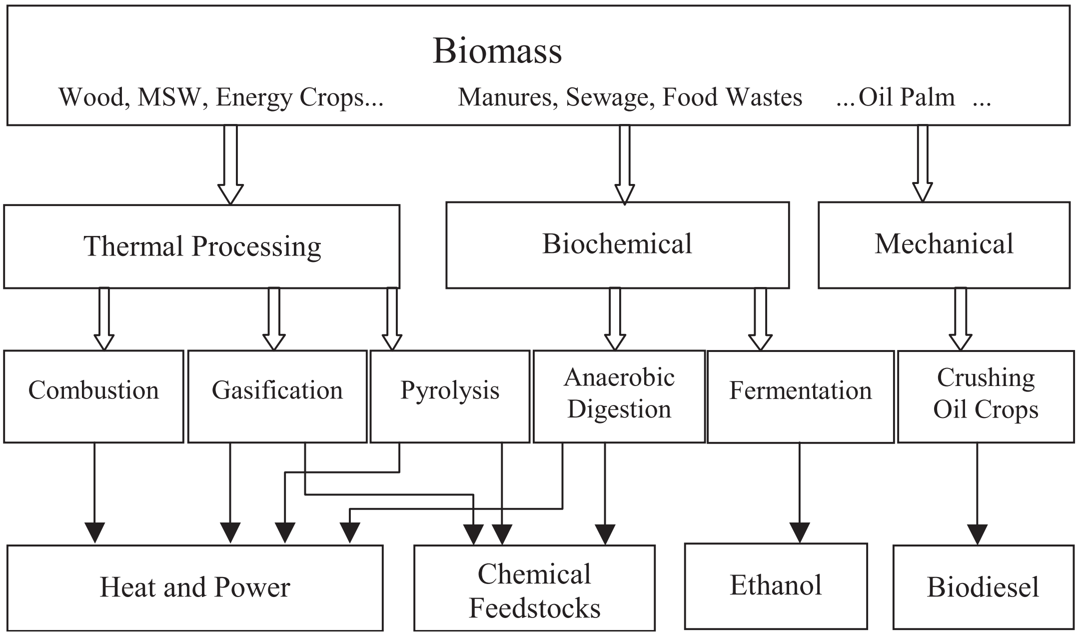

Figure 1: Bioenergy conversion routes.

Scale of bioenergy

At a global level, in 2004, renewables accounted for 13.3% of the 10,579 Mtoe (million tonnes oil equivalent) of the world's primary energy supply (International Energy Agency 2005). This is equivalent to 443 EJ of primary energy supply. Biomass and waste (97% of which is biomass) represented almost 80% of the total renewables, followed by hydro at 16.5% of the renewables component. Biomass as a primary energy source is of the same order of magnitude as natural gas, coal and oil and is more than double nuclear energy.

When one considers only electricity, renewable electricity is the third largest contributor at the global level, after coal and gas and ahead of nuclear and oil. In 2004 renewables accounted for 17.6% of the total global electricity production. 90% of the renewable electricity was produced by hydro power plants, followed by biomass and waste at 6% of the renewable electricity component. Although fast growing, geothermal, solar and wind accounted for less than 4% of renewable electricity in 2004. In 2004 it was estimated that installed biomass electricity generating capacity in OECD countries totalled approximately 25,000 MW. Of this 13.6 GW was solid biomass, 6.8 GW municipal solid waste, 2.6 GW gas from biomass and 2.7 GW of capacity was non-specified combustible renewables and wastes.

As such bioenergy is an important contributor to world energy supplies. In Australia, biomass contributes approximately one percent of the bioelectricity energy mix, with sugar cane bagasse dominating at 368 MW installed capacity. Landfill gas contributes approximately 105 MW, with other major contributions from sewage gas and black liquor (BCSE 2004).

Greenhouse gas emissions

As noted above, bioenergy is essentially carbon dioxide neutral. This is recognised under the Kyoto Protocol. However, even when one takes into account the fossil fuels used in the production, harvesting, transportation and fuel processing of the biomass, the net carbon dioxide emissions associated with a bioenergy plant are generally very small and only approximately five percent of that of a coal fired power. This is illustrated in Table 1 which compares the life cycle emissions of carbon dioxide (equivalent) emissions of several fossil fuel and renewable energy sources.

Table 1: Life cycle carbon dioxide emissions for various technologies (g/kWh).

Technology	g/kWh CO_2
Coal: Best Practice	955
Natural gas: in combined cycle plant	446
Onshore wind	9
Hydro - existing large	32
Hydro – small-scale	5
Decentralised photovoltaic (PV)- retrofit	160
Decentralised PV – new houses	178
Bioenergy – poultry litter - gasification	8
Bioenergy – poultry litter – steam cycle	10
Bioenergy – straw – steam cycle	13
Bioenergy – straw - pyrolysis	11
Bioenergy – energy crops - gasification	14
Bioenergy – forestry residues – steam cycle	29
Bioenergy – forestry residues - gasification	24
Bioenergy – animal slurry – anaerobic digestion	31
Landfill gas	49
Sewage gas	4

Source: DTI 1999.

Bioenergy technologies

Bioenergy is well established, with some 90 percent of modern bioenergy plants using combustion for providing heat and power. The quest for greater energy conversion efficiency has led to the development of gasification and pyrolysis bio-oil technologies, which allows the adoption of combustion turbine technologies and opens the way to combined cycle operation (where the hot exhaust gases from the combustion turbine are used to raise steam, which drives a steam turbine and produces additional electricity from the same fuel source). The major bioenergy technologies are summarised below.

Combustion and co-firing

Two main technologies dominate biomass combustion, grate combustors and fluidised bed combustors. Each of these main technologies has variants, customised for the specific fuel and project conditions. Grate type combustors may be travelling grates, vibrating grates, or pin-hole grates. Fuel is generally introduced into the combustor via an auger or a spreader-stoker. The fuel then moves across the grate, drying, devolatising, burning, with the residual ash being removed via a variety of methods. The fly ash is often used as a soil amendment, while bottom ash can be used as road base. Biomass ash is often free of toxic metals associated with coal ash and the volumes are generally much less. A grate combustor is used in the Rocky Point, Queensland 30 MW cogeneration plant which for part of the year is fuelled on wood waste.

In fluidised beds, the biomass is introduced into a hot, inert bed, (such as sand), where small quantities of biomass (generally a few percent of the bed mass) are combusted. Fluidised beds operate at approximately 850°C, which results in low NOx formation. Sulfur emissions can also be limited, if necessary, by adding limestone or dolomite to the bed. A variant of the bubbling fluidised bed combustor (FBC) is the circulating FBC. A prime example of the circulating FBC technology may be found at the Alholmens Kraft pulp and paper mill in Finland, where the world's largest biomass boiler has a capacity of 550 MW_{th} and 240 MW_e.

A third variant of combustion technologies, is the milling and dust firing of wood pellets in large boilers. This is exemplified by the Avedore 2 unit in Denmark where wood pellets provide up to 70 percent of the input energy in a 590 MW electricity power station unit. Wood pellet firing has become a major aspect of bioenergy, particularly in Europe.

Co-firing or co-combustion of biomass with coal and other fossil fuels can provide a near term, low risk, low cost option for producing renewable energy while offsetting the use of fossil fuels. Co-firing involves utilising existing power generating plants that are fired with fossil fuels (generally coal) and displacing a small proportion of the fossil fuel with renewable biomass fuels. Biomass typically provides between 3 and 15 percent of the input energy into the power plant. In this way a similar proportion of the energy produced is attributable to the renewable fuel fed into the power plant. In general, co-firing biomass is accepted as a source of renewable energy. However, in Australia it does not qualify as 'Green Power'.

Co-firing has the advantage of avoiding the construction of a new, dedicated, bioenergy plant. An existing power station is modified to accept the biomass and to produce a minor proportion of its electricity from that biomass. No new generating plant is needed. Besides requiring a low capital investment cost, co-fired biomass is converted into energy at a conversion efficiency essentially the same as a large, coal fired power plant, which is usually more efficient than a dedicated bioenergy plant producing the same amount of renewable energy.

Gasification

Whereas combustion operates in an oxidising atmosphere, with excess air, gasification occurs in a reducing atmosphere, with starved air, oxygen or by steam injection. A low or medium calorific value, combustible gas is produced, generally consisting of carbon monoxide, hydrogen, methane and low quantities of other gases. After cleaning, this gas can be used to fuel spark ignition engines, be dual fired with diesel, fired in a gas turbine, or with purification it can used as a feed for fuel cells. A number of large scale biomass gasification technologies have been trialled and are under development. A prime example is a Biomass Integrated Gasification Combined Cycle plant at Värnämo, Sweden (see Plate 1) which has operated for several thousand hours in both gasification and full combined cycle mode. Another innovative project is the Güssing gasification combined heat and power plant in Austria, which provides 2 MWe and 4.5 MWth energy. There are also several sub-megawatt gasifiers on the market and these are generally used to provide fuel for furnaces and to power reciprocating engines.

Plate 1: Värnämo BIGCC plant, Sweden.

Pyrolysis

Pyrolysis is the thermal fractionation of biomass, to produce liquid, gas and solid products. Slow pyrolysis is well known for manufacturing charcoal. Recent developments have been directed towards fast pyrolysis. Fast pyrolysis is a high temperature process that converts up to 75 percent of the biomass into a liquid bio-oil, which has a very similar chemical elemental composition to the original biomass. This bio-oil can be used as a fuel in a diesel engine, a gas turbine, or in a furnace, or it can be used as a renewable chemical feedstock. Bio-oil typically has a heating value, on a volume basis, of about sixty percent that of conventional fuel oil. Canadian company, Dynamotive has recently constructed a 100 t/d bio-oil plant in Ontario. The bio-oil from this plant will power a 2.5 MW gas turbine in a ground breaking bio-oil co-generation project.

Emerging technologies for heat and power

Technical developments have been aimed in part at developing higher efficiency, modular power systems, for the distributed power market. These have included Stirling engines, micro-turbines in the range 30-120 kW and fuel cells for both stationary and transport applications. At the present time, their application for bioenergy is either at the development or early commercial deployment stage.

Liquid biofuels

Biomass is the only renewable energy source which can be used for not only producing heat and power, but also for liquid transportation fuels. Several pathways exist. Sugars and starches in various biomass varieties can be fermented to ethanol; oil seed crops can be transestified to provide biodiesel, methanol can be synthesised from gasified biomass and a variety of synthetic fuels can be produced via Fischer-Tropsch chemical processing. These fuels include methanol, dimethyl ether, synthetic diesel and hydrogen. Development of liquid fuels is being driven, not only by greenhouse gas mitigation, but also by rises in the price of petroleum products and the inevitable decline in oil production. Some research relating to hydrogen production from biomass is ongoing, although direct use of biomass is seen to be more prospective in the short to mid term. Several companies including Volkswagen in Germany, Volvo in Sweden and Renault in France are involved in developing and trialing so called second generation biofuels for transportation.

Co-products and co-values

Broadly, the socio-economic benefits of bioenergy are dependent on the nature and scale of the applicable technology and regional economic setting, but would be likely to include some or all of the following:

- *Support for rural and regional development*, stemming rural depopulation and diversification of the local economy.
- *Macroeconomic implications*, including security of energy supply, increased rate of growth, risk diversification, export capability.
- *Supply-side effects*, including increased productivity, enhanced competitive-ness, labour and population mobility, improved infrastructure and economies of supply.
- *Demand-side effects*, including employment, income, induced investment and support for related industries. Demand-side effects embrace direct effects, such as plant construction jobs; indirect effects, such as increased activity in the supply chain which provides materials and services to build the plant; induced effects stemming from successive expenditure linked to the construction and operation of the plant; and displacement effects which reduce the demand for competing activities.

A well managed bioenergy project could also have benefits related to: mitigation of dryland salinity, enhancement of animal habitats and biodiversity, management of wastes, weed management, co-production of products such as activated carbon and biofertilisers, saleable ash and odour reduction (from better management of animal manures).

The Australian bioenergy industry

There is currently close to 600 MW of bioelectricity capacity in Australia, with the dominant contributions being from sugar cane bagasse, land-fill gas, sewage gas and black liquor. Some of the established generating companies are co-firing biomass with coal in large utility boilers. Bioenergy Australia, an alliance of government and industry organisations acts as a forum for fostering bioenergy developments in Australia (www.bioenergyaustralia.org).

Conclusions

Bioenergy has a huge role to play in the provision of sustainable energy. The Clean Energy Future for Australia study (WWF 2004) identified that greenhouse gas emission reductions of some 70% could be achieved by 2040 using several existing technologies and processes. The study found that bioenergy could play a crucial role, providing 29% of the total energy supply mix. However, bioenergy's potential in Australia is yet to be realised and its fortunes will be dictated by incentives such as the Federal Government's Mandatory Renewable Energy Target and various state government requirements for greenhouse gas mitigation.

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