

DELIVERING THE BIOENERGY TRIPLE BOTTOM LINE TO THE GLOBAL COMMUNITY

Ralph E. H. Sims² and Keith M Richards¹

¹Thames Valley Energy Ltd., Newbury, England.

²Centre for Energy Research, Massey University, Palmerston North, New Zealand

ABSTRACT

Global environmental trends are moving towards more sustainable production methods, waste minimisation, reduced vehicle pollution, distributed electricity generation, conservation of native forests, and reduction of greenhouse gas (GHG) emissions. Linked to sustainability goals are development and equity, as sought by the two billion people with no access to electricity. Modern biomass has a role to play in each one of these environmental and social drivers. There are good opportunities for biomass to be used in environmentally sound, small scale, distributed generation systems including fuel cells and micro-turbines, in both developed and developing countries. In all cases the level of greenhouse gas emissions is low or zero. Whether the use of biomass is sustainable and environmentally sound is determined by the source of biomass, land use, alternative treatments of organic wastes, and the type of conversion processes involved.

INTRODUCTION

The *environmental benefits* from the utilisation of modern biomass for energy purposes are well understood. Biomass can provide heat, power, transport fuels, and even alternative material feedstocks substituting for industrial petro-chemicals and plastics. Where the biomass resource is in the form of a waste product or residue, environmental impacts from its usual treatment and disposal can be avoided using one of many waste-to-energy conversion routes. When using any source of biomass to displace fossil fuels, then carbon dioxide emissions are avoided, biomass being carbon neutral due to recycling of the carbon via photosynthesis. In addition to such carbon offsets, when growing energy crops such as short rotation coppice, carbon sink benefits may also be realised when the tree crops are first established into pasture or arable land.

The *economic benefits* of biomass use are not always evident when competing with sources of coal, gas and oil which remain relatively cheap. Where waste disposal costs

can be avoided by using a biomass resource, commercial viability of a bioenergy project can result. Many examples exist including numerous landfill gas projects, and cogeneration through the steam cycle using forest wood residues. For newer developments such as energy crops, transport biofuels, gasification and small scale distributed generation, some form of government incentive or subsidy is usually necessary to encourage implementation of such bioenergy projects. As for many other sources of renewable energy, competing with fossil fuels is a commercial challenge since externalities such as exploration costs and greenhouse gas emissions are excluded from the costs of supply. When international carbon trading begins in earnest, and the carbon sink and offset values of biomass are recognised, then it will become more competitive.

The *social benefits* from modern biomass use relate to improved quality of life, lower emissions of human health harming substances compared with fossil fuel use, local employment opportunities, and other benefits of sustainability resulting from land use change. For many rural populations, particularly for those in developing countries, and for many indigenous peoples, biomass has been traditionally used for cooking and heating. Since these communities are familiar with procuring biomass supplies, the uptake of improved and more efficient modern biomass conversion technologies, including domestic wood stoves and small power generating systems, should therefore be relatively easy to implement. For many communities dependent on imported diesel to run generating sets, and for many others with no access to electricity at all, being able to use local biomass in future to provide not only electricity but heating, cooling and even transport fuels will instill a sense of independence and pride. It may also mitigate the impact of urban drift of young people and provide useful employment opportunities. In developed countries such as the UK, it is considered a significant challenge to almost 'reintroduce' bioenergy to people and communities who have often become alienated from their environment. Nevertheless, there are considerable benefits that will accrue to communities that are willing to develop local 'clusters' of bioenergy projects. Such benefits are explored in a recent study which involved considerable public debate [1].

It is not possible in this paper to cover the specific environmental impacts of each of the biomass conversion routes, to identify which of the systems are environmentally sound and which are less so, and to cover the social benefits for each. The issue is further complicated by environmental impacts usually being project specific and therefore difficult to define in general terms. Details and case studies for each technology are published elsewhere [2]. Therefore the objective of this paper is to outline some generic issues relating to biomass use.

TECHNICAL AND ECONOMIC ISSUES

Conversion into useful energy services and products can be undertaken using a wide range of technological pathways. Biomass projects can vary in scale from simple combustion in domestic open fires; to municipality owned bio-fermentation processes for the treatment of organic waste materials; to fully commercial complex thermo-chemical reactors in the form of 100MW_e combined heat and power stations.

New and improved bioenergy conversion technologies such as gasification, pyrolysis and enzymatic hydrolysis of ligno-cellulose, are being further developed to help solve some of the problems relating to environmental impacts. The aim should be to ensure that, once proven, these are made available as “leapfrog technologies” for uptake in developing countries at prices they can afford in order to provide a more healthy and enjoyable quality of life. Biomass resources and wastes are already widely distributed and people living in rural communities are familiar with their use. However, in future the biomass resource will need to be managed in a more sustainable manner. The challenge is to encourage sustainable production of biomass together with the uptake of efficient conversion technologies, ranging from domestic wood stoves with low smoke production, to large power plants with flue gas emission controls to minimize particulate and any potential harmful gas release. This will take time, effort, investment and political will to achieve. However, as is clear from the IPCC Third Assessment Report [3], biomass has a major part to play in meeting the linked objectives of sustainability, equity and development.

Recent commercial developments in biomass cogeneration, co-firing in coal-fired boilers, biomass-fueled integrated gasification combined-cycle (BIGCC) units for the forest industry, and bio-ethanol from the hydrolysis of lingo-cellulosic material all show good technical and socio-economic potential, with co-firing giving the lowest cost and technical risk. In all cases the capital investment costs continue to decline with project experience. For example, present investment costs for a pressurised BIGCC plant of 20-30MW scale are estimated to fall from over \$US2000/kW to around \$US1100/kW by 2030 when lower fuel supply and operating costs are also predicted.

Liquid and gaseous transport fuels derived from a range of biomass sources are used commercially in a number of countries. These “biofuels” include methanol, ethanol, dimethyl esters, pyrolytic oil, Fischer-Tropsch gasoline and distillate, and biodiesel from vegetable oil crops or tallow. Overall, biofuels can only become competitive with currently cheap crude oil products where significant government support is provided by way of fuel tax exemptions or subsidies, and if a value is placed on the resulting environmental benefits. These can include reduced exhaust emissions in terms of carbon, NO_x and particulates leading to reduced respiratory complaints for city dwellers. However, with certain biofuels additional emissions can result, such as aldehydes from bio-ethanol use and there are questions concerning whether a positive energy ratio exists.

ENVIRONMENTAL AND SOCIAL BENEFITS.

Past assessments of potential energy projects have been based mainly on the economic return on investment. The “triple bottom line” approach now being taken by many energy companies gives greater weighting to social and environmental issues. Environmental benefits from biomass (other than reducing GHG emissions- Table 1) include reducing local emissions, using limited resources better, improving biodiversity and protecting the habitat and landscape (which growing short rotation forests can do well if planned and designed carefully). Reducing waste disposal into landfills and

waterways, avoiding the noise, maintenance and inconvenience of diesel generating sets, and minimizing the need for power lines are other benefits that bioenergy can provide.

TABLE 1.
COST RANGES FOR GREENHOUSE GAS REDUCTION TECHNOLOGIES COMPARED WITH A
CONVENTIONAL COAL-FIRED POWER PLANT, AND THE COST OF CARBON REDUCTION.

Power station type	Carbon emissions (gC/kWh)	Emission savings (gC/kWh)	Generating costs (USc/kWh)	\$/t carbon avoided. (US\$/t)	Reduction potential 2010 / 2020 (MtC/yr)
Pulverized coal – as base case	229		4.9		
IGCC – coal	190 – 198	31 – 40	3.6 – 6.0	-10 – 40	49 / 140
Pulverised coal + CO ₂ capture	40-50	179-189	7.4-10.6	136 –165	10 / 100
CCGT - natural gas	103 – 122	107 – 126	4.9 – 6.9	0 – 156	38 / 240
CCGT gas + CO ₂ capture	14 – 18	211 – 215	6.4 – 8.4	71 – 165	Uncertain
Hydro	0	229	4.2 – 7.8	-31 – 127	26 / 92
Bioenergy IGCC–wood wastes	0	229	2.8 – 7.6 ^a	-92 – 117	14 / 90
Wind – good to medium sites	0	229	3.0 – 8.0	-82 – 135	63 / 173
Solar thermal and solar PV	0	229	8.7 – 40.0	175 – 1400	2.5 / 28

^a Biomass fuels as delivered range from \$0/GJ for on-site waste requiring disposal costs to \$4/GJ for purpose grown energy crops.

From the social perspective there can be little doubt that bioenergy projects protect existing employment, provide new jobs, give learning opportunities, transfer skills, introduce new skills, and provide training and educational opportunities. The trend towards independent power production using smaller scale plants and embedded generation should result in a decline in urban drift once rural communities are able to develop and grow using the new sources of bioenergy available to them. This in turn will produce a sense of pride and independence, of particular importance to many indigenous or aboriginal communities who are struggling to maintain their cultural identities [4]. Local health benefits can also result, as a result of better wood stove designs for people living in rural areas of developing countries, to less pollution from traffic emissions for those living in city centres.

MITIGATION OF ENVIRONMENTAL AND SOCIAL BARRIERS

- Health problems arising from open fires or from poorly designed bioenergy plants which produce high levels of particulate emissions can be overcome by proper installation of clean burning combustors that meet modern air emission standards.
- There is a lack of information available to potential bioenergy plant investors regarding environmental effects and many rely on their own limited knowledge rather than seek and pay for quality advice. In addition, relatively few senior business managers possess good information about their own processing plant, its energy requirements and the emissions. So there is a need to publish information that will assist investors make appropriate equipment selection.
- Monocultural production of energy crops is deemed unacceptable by many environmental agencies and there could be public rejection due to changing landscape values and lack of biodiversity. Planting a mix of species is sometimes worth

considering, not only for landscape benefits but also for added resistance to the spread of pests and diseases and to provide a supply of fuel over a longer period.

- Continuous large scale production of forest plantations and energy crops could reduce soil fertility levels, impact on downstream water use, and lead to leaching of nutrients and increased use of agri-chemicals. Nutrient recycling through the return of the combustion ash and sustainable crop production methods should be practiced.
- The energy balance of biomass is not always favourable, especially for biofuels produced from annual energy crops [5] than for wastes or woody biomass from perennial crops where the energy output is at least 10 – 20 times greater than the energy input. In addition, the collection and transport of biomass often results in increased use of vehicles, higher exhaust air emissions and greater wear and tear on the road infrastructure. Sometimes rail transport can be used to minimize such impacts.
- Land requirements for future energy crop and forest plantations will compete with land used for the traditional production of food and fibre products. The land area used will ultimately depend on biomass crop yields as achieved on a sustainable basis, water availability, and the conversion plant efficiency. For example, for a 20% efficiency, steam turbine plant fuelled by a forest energy crop yielding 15odt/ha/y, 360ha of energy plantation would be needed per MW_e of installed capacity when running the plant for 6000 hours per year. If a 40% efficiency gasification plant was built instead and yields were 20odt/ha/y, then only 135ha would be needed per MW_e.
- There may be a future shortage of skilled workers for harvesting and collecting biomass. So although employment opportunities from greater bioenergy uptake are often quoted, finding willing workers for what can be somewhat arduous and repetitive work may not be easy in either developed or developing countries.

FUTURE FOR BIOENERGY TECHNOLOGIES

In the longer term, the key to sustainability, equity and development, which are inextricably linked with climate change mitigation, will be the development of new and affordable small scale “distributed generation” conversion technologies such as fuel cells, Stirling engines, and micro-turbines as well as internal combustion engines (ICE) running on landfill gas or biodiesel. If fuelled by these or other biofuels such as hydrogen, methane and methanol, then a decarbonised world will be ensured.

Distributed bioenergy power technologies have a wide range of claimed manufacturing costs and efficiencies (Fig. 1). Increased integration of bioenergy with other distributed energy resources could further enhance technology improvement in this sector but the environmental impacts from use of such small scale systems is not clear. For example, wood gasification in poorly designed down-draft plants can lead to the formation of carcinogenic condensates that would need careful disposal. Overall, small scale biomass has good potential to become a significant fuel for distributed energy systems and a possible source of “green” hydrogen (for fuel cell use).

CONCLUSIONS

Traditional biomass continues to provide a significant amount of global consumer energy

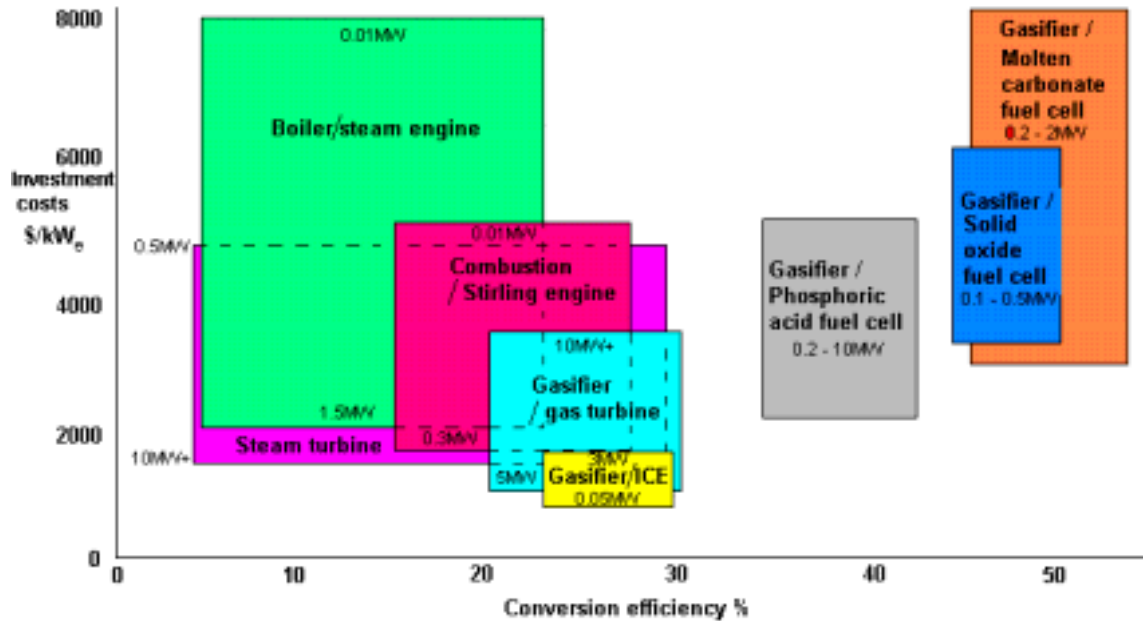


Figure 1. Installed cost estimates (\$US/kW_e) and claimed conversion efficiency ranges of selected existing and emerging small scale bioenergy technologies.

but it is not produced sustainably and has adverse environmental and social impacts. To improve public health and atmospheric emissions, it should be replaced by the many new and improved modern biomass technologies reaching the market. As the carbon dioxide mitigation benefits of biomass become better understood by investors and carbon emissions trading begins, there is likely to be a significant increase in the total installed capacity of biomass fuelled plants.

Within the wide range of commercial and developing bioenergy technologies are many that, after careful life cycle analysis, could be classified as environmentally sound. Others create major environmental impacts. The difficulty is that projects are very fuel and site specific in this regard. Establishing a set of standard project guidelines for use by environmental consenting and project funding agencies to indicate the points to consider for each of a range of bioenergy technologies would be a useful approach.

References

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