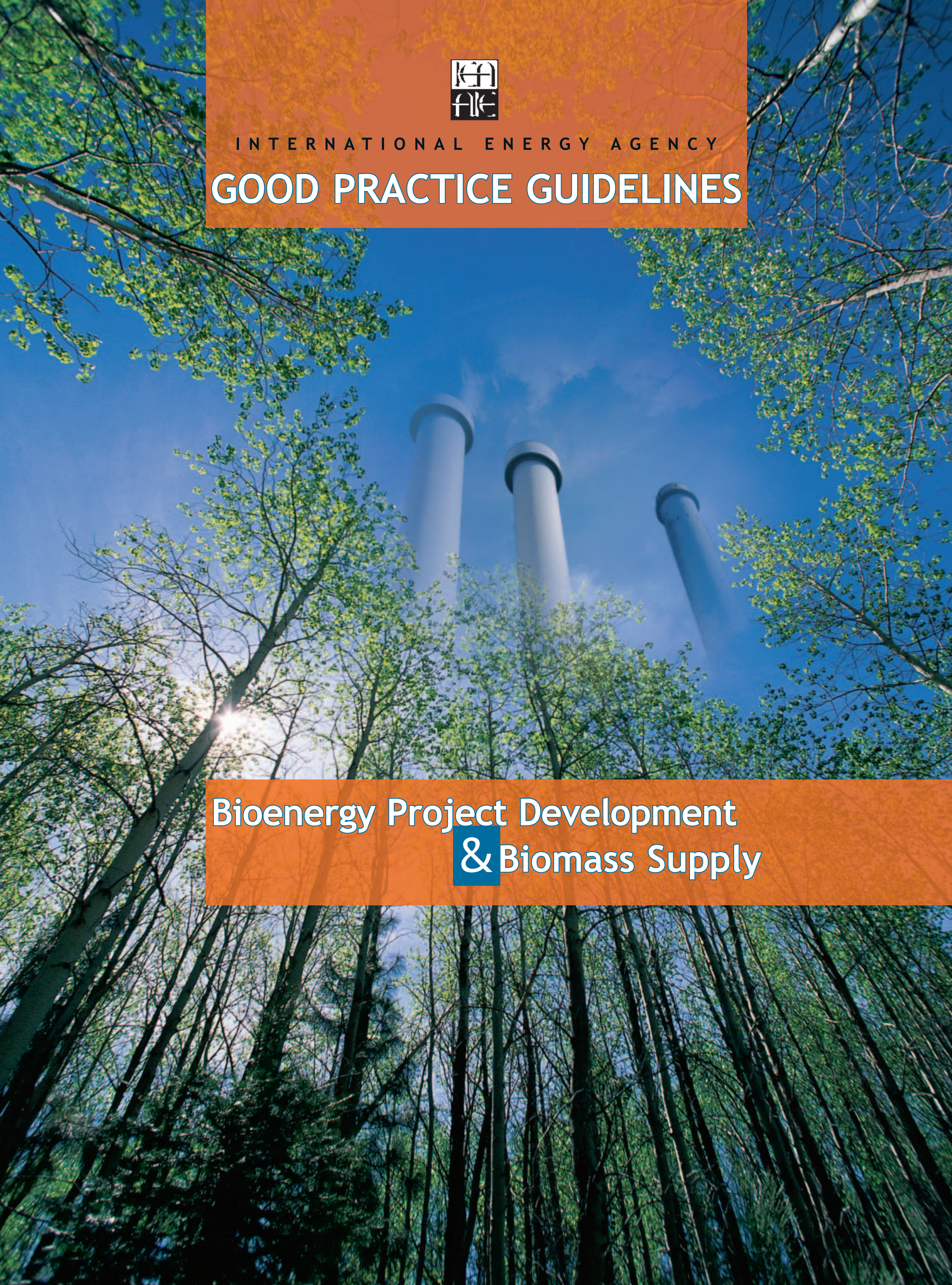
INTERNATIONAL ENERGY AGENCY

GOOD PRACTICE GUIDELINES



Bioenergy Project Development & Biomass Supply

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- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To assist in the integration of environmental and energy policies.

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Acknowledgements

This paper was drafted for the Renewable Energy Working Party of the IEA in March 2007 by Ralph E H Sims of the IEA Renewable Energy Unit. It reflects the views of the IEA Secretariat and may or may not reflect the views of the individual IEA member countries. Review comments were gratefully received from Executive Committee members of the IEA Bioenergy implementing agreement (Chair, Kyriakos Maniatis) and members of the IEA Renewable Energy Working Party. For further information on this paper please contact the Renewable Energy Unit of the Energy Technology Collaboration division, ralph.sims@iea.org

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Executive Summary

Developing a bioenergy project is no easy task. Similar planning issues exist whether the bioenergy plant is a small, on-farm heat plant, a district combined heat and power plant, a utility-owned electricity generating plant, or a large scale commercial biofuels plant.

- The biomass feedstock needs to be available over the life of the plant and produced in a manner that is deemed to be sustainable as well as renewable. It can be in solid or liquid form.
- This feedstock has to be delivered to the conversion plant by road, rail or waterways as cheaply as possible in a form that is easy to store, handle and utilise. The low-bulk density and energy density of many forms of biomass make this a particular challenge.
- The quality and moisture content of the feedstock need to be assessed on delivery to ensure efficient conversion and fair means of payment.
- Where the biomass is to be imported, certification of its source and the identification of low-cost transport methods, in both financial and energy terms, need consideration.
- Selection of the energy conversion technology and size of plant should be based on the nature of the biomass, the volume available, the reliability and the risk of failure from immature technologies.
- Markets for the bioenergy carriers produced (as heat, electricity, gaseous fuels, liquid biofuels, or solid fuels such as pellets) need to be assessed and purchase agreements sought where feasible.
- Design and construction of the bioenergy conversion plant, choosing its location, the proximity to power, gas and water supplies, and obtaining the necessary resource and planning consents, can be major barriers requiring solution by the project developer.

These *Good Practice Guidelines* do not analyse the technologies or costs of a bioenergy plant but endeavour to identify the potential issues for bioenergy project developers that will need to be overcome during the complex planning and consultation process. For example a cogeneration plant at a sugar mill in Australia took two years to develop and required 17 separate legal contracts to be negotiated. It is hoped that a greater awareness of the potential barriers by fuel suppliers, developers, planners, consenting authorities, policy makers and other stakeholders from the outset will aid the consultation process. This in turn will help to enable a more rapid deployment of bioenergy projects worldwide.



Introduction

Rationale and objectives

Modern biomass, and the resulting useful forms of bioenergy produced from it, are anticipated by many advocates to provide a significant contribution to the global primary energy supply of many IEA member countries during the coming decades. For non-member countries, particularly those wishing to achieve economic growth as well as meet the goals for sustainable development, the deployment of modern bioenergy projects and the growing international trade in biomass-based energy carriers offer potential opportunities.

However developing a bioenergy plant can be a challenging process. Securing reliable and cost effective supplies of biomass feedstocks, produced in a sustainable manner over the operating life of the plant, can prove to be difficult.

This paper endeavours to facilitate the development of bioenergy projects by providing a discussion of good practice guidelines for use by policy makers, local resource consenting authorities, plant developers and biomass feedstock suppliers. Whether the project is designed to provide electricity, heat, cogeneration of heat and power, liquid biofuels for transport, or a range of products from a bio-refinery is incidental.

The overall aim is to ensure that proposals and planning for a bioenergy project can proceed expediently and in an appropriate manner. This will help to ensure that the bioenergy industry maintains its reputation of being responsible with regard to minimising the potential environmental and social impacts that a project might bring to a community.

The paper does not attempt to describe and evaluate the various production and conversion technologies related to biomass and bioenergy or their costs. These are extremely well covered within the IEA Bioenergy Implementing Agreement and its various activities (IEA Bioenergy, 2007) and in a recent overview paper (Faaij *et al*, 2007).

The essence of good practice

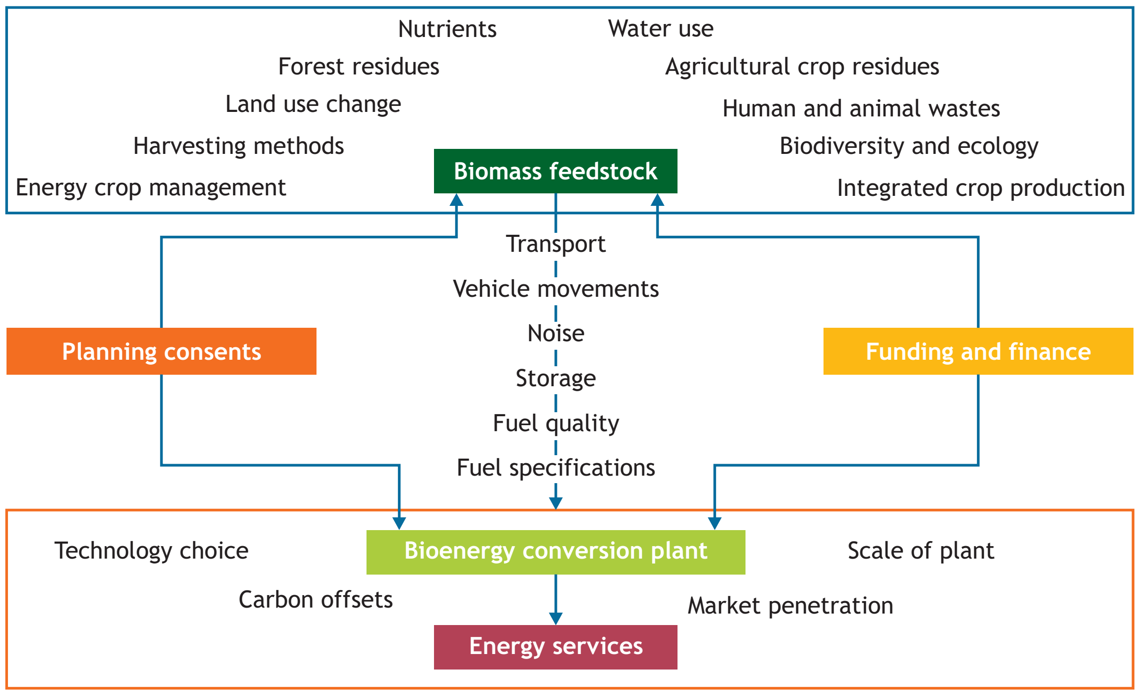
As well as evaluating the *economic viability* of a project, a developer will need to consider any related *social issues* together with *environmental impacts*. Bioenergy projects are usually considered to be environmentally acceptable at the national and international level in that they provide renewable sources of energy with low or even zero greenhouse gas emissions. However as for any energy project, they can also have local impacts (Figure 1) so are not always readily acceptable to people living and working nearby. This applies whether the project is a large scale, commercial, biofuels plant requiring an all-year-round biomass supply chain, a farmer co-operative owned biogas plant supplying bioenergy services to a local community, or a small heat plant for the biomass supplier's own use on site. Consultation with the local community together with early discussions with the local and regional resource consenting authorities, such as local councils, are essential in all cases.

Producing a step-by-step guide for planners and developers is not practical. Bioenergy projects can range from a small (~40kW) local on-farm heating plant to a large (~400MW) commercial cogeneration plant. Therefore not all projects will experience the same issues relating to their planning and development. There will also be major variations in the regulations imposed by local, regional and national governments. Consequently not all aspects discussed here will be relevant for even bioenergy schemes of similar scale and type.

This discussion document simply aims to present the range of issues and basic principles involved. To undertake good practice, these issues will need to be considered by developers, even of small schemes on private property. The same issues will need to be addressed by local decision makers in order to produce their own planning guidelines and regulations specific to local conditions. It is therefore imperative that proper advice is sought from the local authority at an early stage and that official regulations are adhered to.

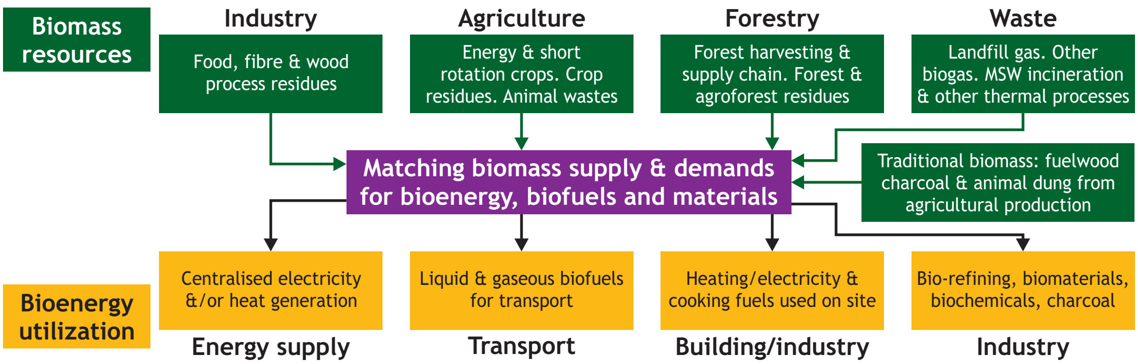
The public image of biomass feedstock production and bioenergy conversion plant operation remains contentious in many locations. This is often due to a lack of understanding by objectors rather than from any first hand experience of poorly designed and managed plants. "Good" projects are designed to remain sustainable in the long term based on full life cycle analysis. "Bad" projects are usually designed to maximise the short-term profit of the investors with little consideration for the wider issues involved. For the future long-term ability of the global biomass industry to reach its full potential, it is important that the current image is enhanced and does not become tarnished. Greater education concerning the benefits of bioenergy and biofuels and improved dialogue between stakeholders to better understand the diverse range of views is therefore warranted.

Figure 1 • *Bioenergy projects require consideration of environmental and social issues*



Related social issues such as community cohesion, employment, rural development, waste avoidance and health benefits can be of equal importance (though are not shown here).

Figure 2 • *Biomass resources converted to bioenergy carriers*



Eventually the energy carriers provide a range of useful energy services as well as co-products at both the large and small scales

Biomass feedstocks originating from a wide range of sources can be converted in many different types, designs and scale of plants to provide useful forms of bioenergy carriers (Figure 2).

The role that biomass will play in the future global mix of consumer energy supply will not solely depend on the many technologies which exist nor on further R & D investment to improve their efficiencies. It will also depend upon the ability to overcome the barriers that inhibit project development and constrain sufficient commercial investment. For a project to be "bankable", investors must have confidence that it will proceed satisfactorily without delays and will continue to operate profitably over a long term period.

In this regard eight broad questions need to be asked by bioenergy project developers, stakeholders, decision makers and investors.

- What types and amounts of biomass resources are available or can be produced sustainably?
- Are there competing uses for this biomass and would its use for energy purposes impact on other industries?
- What suitable supply chain and conversion technology developments available now, or in the near future, will enable environmentally acceptable bioenergy products and energy carriers to be generated more efficiently than at present?
- In terms of preparing an environmental impact assessment in order to gain planning approval, what impacts will the increasing use of biomass in a region have on the local environment and on water supplies?
- Will beneficial social issues result such as employment, rural development, social cohesion, improved health, equity and development?
- What level of investment will be needed to establish the proposed bioenergy project, not just for plant construction, operation and fuel purchase but also for obtaining the necessary consents and negotiating the relevant legal contracts which can be numerous?

- What markets for the bioenergy carriers exist now or will be established in the future?
- What is the level of risk from investing in such a business, including competition from other energy supply systems (such as wind, geothermal and fossil fuels), and investments in energy efficiency measures that, if successful, could avoid the need for additional energy supply?

The last three questions on investment, markets and risk belong to the business proposition for a commercial bioenergy investment and are not directly relevant to the objectives of this paper. The first five questions relating to environmental and social barriers and benefits of a bioenergy project are discussed below as:

- Section 1. The biomass resource;
- Section 2. Delivering the biomass and producing the bioenergy carriers; and
- Section 3. Overcoming barriers and encouraging benefits.

Section 1

The Biomass Resource

What types and amounts of biomass resources are available and can they be provided and produced in a sustainable manner, both environmentally and socially, over the long term?

How much biomass do we have?

Biomass is basically a stored source of solar energy initially collected by plants during the process of photosynthesis whereby carbon dioxide is captured and converted to plant materials mainly in the form of cellulose, hemi-cellulose and lignin. The term "biomass" therefore covers a range of organic materials recently produced from plants, and animals that feed on the plants. The biomass can be collected and converted into useful bioenergy. It includes crop residues, forest and wood process residues, animal wastes including human sewage, municipal solid waste (MSW) (excluding plastics and non-organic components), food processing wastes, purpose grown energy crops and short rotation forests (Figure 3).

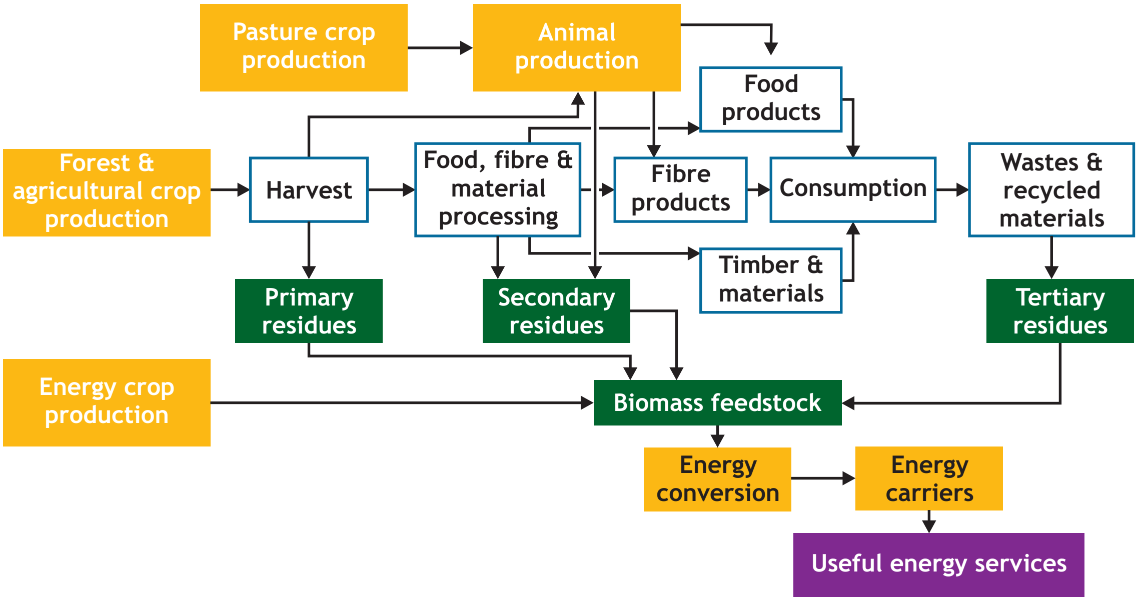
Traditional biomass, mainly in the form of fuelwood or dried dung, has long been the energy source for cooking and heating and remains so for around one third of the world's population. This resource is usually gathered and scavenged rather than being sold commercially (perhaps with the exception of wood charcoal) so it is not considered here, other than where the opportunity exists to use the available biomass more sustainably and efficiently as feedstock for modern bioenergy plants.

Since around 10 000 years ago when agricultural production began, cultivated crops have provided human food, feed for animals, a source of construction materials, and fibre for cloth or paper production. Harvesting of food and fibre crops to provide the main products by using the industrialised agricultural production methods of today, results in *primary residues* being left in the field or forest. *Secondary residues* arise from food, fibre and material processing and as animal production wastes. Other waste materials arising after use of the main product such as demolition timber, sewage sludge, and MSW can be classified as *tertiary residues* (Figure 4). All of these can be used as biomass feedstocks since they contain some useful energy value that can be captured.

Figure 3 • *Examples of biomass resources*

Clockwise from top left: plantation forest thinnings; the solid "green" fraction of MSW from demolition timber, pallets and garden refuse; energy crops such as oilseed rape; cereal residues such as straw as used in heating plants; traditional fuelwood; bark residues accumulated at a pulp mill; short rotation coppice eucalyptus crop; oil palms grown for biodiesel feedstock; and forest arisings remaining after harvest and extraction of stemwood logs.

Figure 4 • *Biomass feedstocks arising from residues and energy crops*



The solid or liquid biomass feedstock can be converted using numerous technologies to provide more convenient energy carriers in the form of solid fuels (*e.g.* wood chips, pellets, briquettes), liquid fuels (*e.g.* methanol, ethanol, biodiesel, bio-oil), gaseous fuels (synthesis gas, biogas, hydrogen) or direct heat (Figure 5).

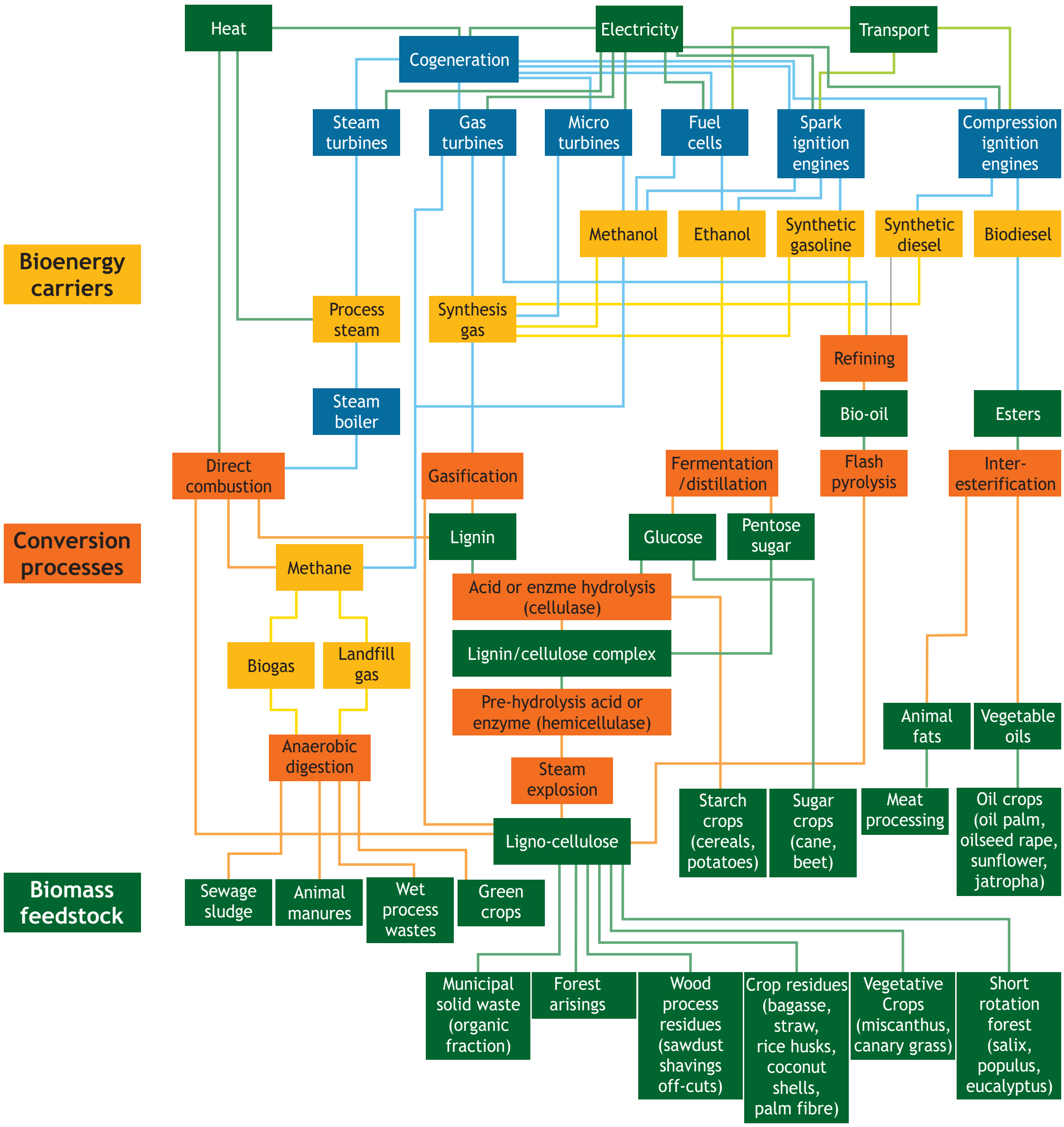
Just as from oil, gas and coal (which all began as biomass many millenia ago), a range of chemical products can also be co-produced from biomass. The concept of developing a bio-refinery to produce multi-products from a single feedstock similar to an oil refinery has promising potential. Some high value chemical products, such as polymers or furfural, could be produced in small volumes whilst other products, including useful heat and electricity, tend to have lower value but could be produced as large volume outputs.

Multi-product plants already exist in the form of large scale, commercial sugar mills, pulp mills, rice mills etc. where the main product is sugar, paper pulp or rice, but the “waste” bagasse, black liquor or husks can also be used for heat and power generation for use both on-site and for export. Similarly vegetable oil processing plants to produce biodiesel usually also produce a high protein meal for feeding livestock, straw, stover or kernels suitable for combustion for heat production or pulping, and glycerol that can either be upgraded to glycerine for use in cosmetics and explosives, or, once in surplus supply with a low value, could possibly be used as another energy feedstock.

Assessing the biomass resource

There is a need for policy makers to better understand the biomass resource base, its measurement, the potential competition for its use for non-energy purposes, constraints from land use and water uptake, nutrient recycling and replacement, and the benefits and disadvantages from the utilisation of biomass on a sustainable basis. Some forms of biomass such as wood process residues have been utilised as a combustion fuel for decades. Others such as specialist energy crops including *Miscanthus*, *Jatropha*, short rotation *Salix* (Figure 6) and *Eucalyptus* etc. are new and there is still much to learn about their production, harvesting, storage and processing.

Figure 5 • *Biomass feedstocks converted to bioenergy carriers*



Examples of the wide range of solid, liquid and gaseous biomass resources that can be converted using numerous technologies and pathways to provide bioenergy carriers in the form of heat, electricity and transport fuels from which useful energy services can eventually be obtained. The developer of a bioenergy project can start at the top of this chart and determine the options available to produce the preferred energy carrier whereas the owner of a biomass resource can start at the bottom and consider the options for its conversion.

Residues from agriculture, plantation forests and food and fibre processing operations are collected worldwide and used in a wide variety of bioenergy conversion plants. These are difficult to quantify. Obtaining accurate data on the biomass resource available even in a local district can be challenging as it varies from year to year and across seasons. A very useful publication, the *Biomass Assessment Handbook* (Rossillo-Calle *et al*, 2006) helps provide the tools needed to understand the biomass resource base and its assessment, whether it be for woody biomass, herbaceous biomass, or crop residues. Measuring tree volumes, assessing the moisture content of a truck load of wood chips, calculating the energy content of a field of straw, using remote sensing techniques to measure variations in crop yields in a district, are just a few examples of the challenging tasks needed for accurate biomass resource assessment. Changes to carbon fluxes and carbon stocks from growing energy crops, including any effects on soil carbon content, are also difficult to measure and monitor (Figure 7).

Where sufficient data is available, GIS (geographical information systems) and overlay mapping techniques can be used to identify known biomass resources or to match proposed energy crops with current land use, soil types, rainfall and sunshine hours. This can also be a powerful tool to identify the best location/s for a proposed bioenergy plant, depending on the volume of biomass needed per year, the nature of the roads for transport, and access to existing power lines. Where the international export of large volumes of biomass is anticipated, good rail or road access or close proximity of the plant to a port is essential.

Figure 6 • *Harvested Salix (willow) stems awaiting collection*

Recent coppice re-growth evident in the foreground and 2-year rotation biomass in the background.

Figure 7 • *Greenhouse gas balances include soil carbon stocks under plantation*

Establishing the GHG balances requires all processes involved in the use of bioenergy systems on a full fuel-cycle basis to be assessed (IEA BioenergyGHG, 2007).

Moisture content, dry matter content and heating values

Most forms of biomass contain water to varying degrees and this effects the energy content of the material. Measuring the moisture content is critical for solid biomass assessment and also when purchasing it to determine a fair value. It can be achieved by taking samples (Figure 8), weighing them, oven drying at around 90ºC until constant weight, then reweighing the remaining dry matter to calculate the moisture that has been driven off. Using electronic instruments such as conductivity probes pushed into a pile of straw or wood chips is more rapid – though their accuracy can vary.

Evaluating the available biomass resource from a region, or indeed for a single bioenergy heat or power plant, must account for the moisture content which can vary considerably and hence complicates the assessment. The atmospheric ambient conditions, (mainly temperature, air movement and humidity), together with the structure of the tissues of the specific biomass, determine the natural release of moisture from the biomass by transpiration and evaporation, and hence the drying rate. A branch or tree with leaves left on after felling results in faster transpirational drying taking place to bring down the moisture content of the stemwood.

The interactions between moisture contents, dry matter losses in storage over time, heating values and biomass bulk densities need to be understood as they affect the overall costs of transport, storage and conversion of the biomass (Section 2).

Figure 8 • *Sampling biomass on delivery*

Tests undertaken for various parameters including moisture content are standard procedure at large biomass plants to ensure quality factors are maintained and a fair means of payment to the supplier can be assessed rather than be based on tare weight alone.

The moisture content of slurries and wet biomass feedstocks, as used with anaerobic digestion or fermentation plants, are less important than for solid biomass since the feedstock is usually not transported long distances and will not deteriorate. The total solids content of a liquid can however have an effect on the biogas plant efficiency and the cost of storing larger volumes. Also it may need to be determined when the wet crop, slurry or effluent is traded.

Long-term biomass supply

Using biomass from the by-products of a crop or process (often classified as "waste") makes good economic sense. However there is a limit to the amount available depending on the area of crop grown for its primary products and the amount of waste product from a process. Many businesses are attempting to minimise their wastes by either improving the process or utilising the material for co-products other than energy. So over time the volumes available of a "waste" biomass resource could decline.

Increasing the available supply of biomass in future could therefore depend to a greater degree on the active production of energy crops on surplus arable land (as in Europe and the USA), marginal and degraded lands, or plantation forests. However purpose grown energy crops are unlikely to become economic within the next decade without introducing direct supporting policies unless they can produce multi- products or demonstrate co-benefits such as acting as a hedge against future fuel supply risks.

Another co-benefit is that, with careful management, improved quality of degraded soils can result. For example, in Australia millions of hectares of high salinity soils (now resulting from historic tree clearing) are being renovated by growing strips of oil mallee trees (a species of eucalyptus harvested for biomass) to drive down the salt by lowering the water table across cereal growing land (Figure 9). Also where energy forests or crops are grown as riparian strips, then the quality of nearby waterways and lakes can be improved by reducing the nutrient loadings from the run-off of animal wastes or from excessive application of fertilisers. On the other hand, if crops are poorly managed, then increased biomass production can lead to losses of terrestrial carbon and the degradation of biological diversity.

Bioenergy conversion facilities often operate with uncertain fuel supplies because the low value biomass fuels currently available could become potential feedstocks for newly developing markets. Potential investors in bioenergy facilities will be cautious about projects with a lifecycle of 15-20 years where there is uncertain fuel availability at no fixed prices, and hence the project is exposed to market risks. Therefore negotiating long-term contracts with the fuel suppliers to maintain security of supply, as well as to improve fuel quality, is highly recommended to reduce these risks.

Figure 9 • *Eucalyptus oil mallee trees grown in strips*

The trees planted to drive down the water table to overcome dryland salinity problems in Western Australia become a source of biomass.

Can the biomass be produced and used in a sustainable manner?

A significant barrier to the use of biomass in some regions is the public concern that its production is non-sustainable. In some instances, such as if harvesting native forests at a rate greater than their rate of natural regeneration, this view is clearly correct. There are simply some sources of biomass that for a variety of reasons (such as their aesthetic, recreational, biodiversity, water cycle management and carbon stock qualities) should never be used for energy purposes. However for other sources this is not always so clear cut. The debate continues on what exactly is the definition of 'sustainable biomass' (Figure 10). Harvesting indigenous forests for biomass would not normally be seen to be sustainable, though sustainable harvesting of forest products can have legal status as in Austria. Certification schemes, criteria, indicators and guidelines for biomass defined as being sustainably produced are under discussion (see for example www.pefc.at and www.globalbioenergy.org).

Figure 10 • *Rejected logs and arisings after harvesting of stemwood*

Residues in this Australian eucalyptus regrowth forest being considered by staff of Shell International Renewables as to whether their extraction for biomass feedstock would be acceptable or not as a sustainable activity.

Residues from plantation forests that would otherwise be left to decay, and wood process residues that would otherwise be disposed of in landfills, probably are sustainable forms of biomass. Growing sugarcane for ethanol production and using the bagasse for heat and power generation possibly is sustainable as long as the soil nutrients are well managed and any nutrients removed at harvest are eventually replaced. However the intensive production of corn for ethanol production, or oilseed rape for biodiesel production, needing relatively high inputs of fossil fuels, nitrogenous fertilisers and agri-chemicals possibly is not, depending on the definition of "sustainability". The Global Bioenergy Partnership, established by the G8 meeting at Gleneagles in 2005 is investigating this in association with the IEA Bioenergy Implementing Agreement, Task 40 *Sustainable Bioenergy Markets, Trade and Resources* (see www.bioenergytrade.org).

The industry needs to clarify this issue immediately since public concerns about the environmental impacts from using biomass as an energy source lead to a number of frequently asked questions.

- Will the use of land for energy cropping reduce the area of land now used for food and fibre production so that scarcities will result?
- Will genetically engineered trees and crops need to be developed specifically for use for biomass energy supplies?

- Will soil nutrient levels be depleted by continually removing large quantities of biomass material such as crop residues from the land to supply nearby conversion plants?
- Will biodiversity be further threatened and agri-chemical use increase if ever greater areas of monocultural crops are grown?
- Will planting large areas with fast growing trees as energy forests reduce both water run-off and percolation into the groundwater, thereby affecting downstream users?
- Will transport of large quantities of biomass to the power plants result in increased traffic congestion, noise, dust, road damage etc?
- Will an increasing number of wood-fired heat and power plants lead to an incentive for investors and shareholders to support the cutting down of existing forests?
- Will stack emissions from municipal solid waste-to-energy plants, and also possibly from wood-fired biomass plants, contain toxic substances such as dioxins?
- Will using waste for energy purposes reduce the desirable incentives to minimise and recycle waste materials if it is cheaper to burn it?
- Can biomass be produced in a truly sustainable manner as well as being renewable?

This following section aims to clarify some of these issues, with other issues relating to biomass delivery and bioenergy conversion plant, planning, construction and operation covered in Section 2.

Source of residues and wastes

Organic residues and wastes from the primary sector are often cost effective feedstocks for bioenergy conversion plants. As a result many of today's commercial bioenergy plants around the world have resulted from niche market opportunities within the forest, food production, food processing, and other primary industry sectors where on-site biomass "waste" feedstocks are available and have required treatment or disposal. Where the biomass fraction has already been delivered to the site along with the primary product, such as corn cobs, tree bark, and animal fat, the biomass value (USD/GJ) is usually more competitive and there may even be an avoided disposal cost. For example the lignin content of black liquor (the residual material from the wood pulping process) is commonly used as a heat source in pulp mills; wet wastes suitable for biogas production are used on farms and in food processing plants; and dry wastes such as sawdust, rice husks and palm oil kernels are combusted onsite in boilers to provide cheap process heat for the factories. Bagasse is another important residue for cogeneration, with particular potential in non-OECD countries that grow sugarcane.

Other biomass materials normally left in the field at harvest, such as cereal straw, forest arisings (tree branches and tops) and sugarcane trash, can be collected and stored as fuel for heat and power plants. This is less common as the additional costs for collection, transport and storage increases the total delivered cost of the biomass fuel (in terms of USD/GJ) to the conversion plant gate. Hence it competes less well with purchased electricity, gas or coal.

Woody weeds

Where non-native trees have established naturally after their unintentional introduction, possibly following the introduction of an exotic species for non-commercial purposes, such as gorse in New Zealand or mimosa in Northern Australia, then land clearing is encouraged to control the spread of the species. The biomass collected could then become a useful fuel. The limitation however is the long-term supply of the resource. If complete eradication is successful after maybe 5 or 10 years, by which time the land will have begun to revert to its former native vegetation, no more biomass supply is available. Therefore a bioenergy plant using the feedstock would become short of fuel. Dependence on a single feedstock is often risky anyway. So plant designs to handle multi-feedstock are recommended where feasible but are more difficult to design.

Land use change to energy crops – competition with food and fibre

Land requirements for future energy crop and energy forest plantations compete with land used for the traditional production of food and fibre products. Land use change will only happen on a large scale if the landowners can gain more revenue or other benefits from growing a new energy crop than is being received from the traditional crops currently being grown. The difficulty is that traditional forms of energy remain relatively cheap so energy crops have to compete with these low USD/GJ prices. Conversely to grow an energy crop requires inputs of seed, fertiliser, chemicals, machinery, fuel, labour etc. and hence requires a good sale price in order to compete with the revenue received from growing other crops. In essence biomass already collected at a site (such as bark at a pulp mill) is cheaper than collecting more dispersed biomass residues (such as forest residues), which in turn is cheaper than growing purpose grown energy forests.

Therefore to make energy cropping a viable business proposition for a landowner, either agricultural subsidies need to be introduced or adjusted to encourage energy crop production over food and fibre crop production, or the co-benefits from growing the crop need to be better valued. These can include landscape enhancement, wild life habitat, improved water quality, rural development, employment opportunities, carbon sequestration, etc. 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. New crops can have a major visual impact such as when oilseed rape was first introduced in the UK which is bright yellow when it flowers. Whether the impact on the landscape is seen to be beneficial or negative depends on perception by an individual, where it is grown, the character of the existing landscape, and how intensive the crop becomes within a concentrated area. Developers and growers could undertake a landscape assessment process in order to better understand and communicate the impacts on the landscape (see Section 3).

The area of land needed to grow energy crops will ultimately depend on the annual yields of biomass as achievable on a sustainable basis, water requirements and water availability, recognition of co-benefits, government support schemes, and the conversion efficiency of the resource to useable fuels or energy carriers. As an example 240 ha of energy forest plantation yielding 15 oven dry tonnes (odt) /ha/y of woody biomass would be needed per MW_e of installed capacity to supply a wood-fired power plant with 35% efficiency conversion of fuel to electricity when running for 7 000 hours per year. For a CHP plant of say 70% efficiency less of the solar energy stored in the biomass would be wasted as useless heat.

Careful site selection may also reduce the need for control of pests, including rabbits, gazelle, deer etc. by costly fencing, as well as weed control and diseases by agri-chemicals.

Sustainable land use

Harvesting of biomass on a non-sustainable basis for bioenergy, or indeed to produce other products, or clearing native forests to provide more agricultural land, are considered unacceptable to most people.

This land clearing practice is continuing in several world regions but usually the standing or cut forests are burned in the field with no consideration to use the biomass for energy. The loss of a carbon stock and resulting increase in atmospheric carbon content are serious concerns as is the loss of biodiversity.[1]

Even where native forests have been harvested then allowed to fully regrow before re-harvesting, such as is common practice for Eucalyptus forests in Australia, Scots pine in UK, and Norway spruce in Scandinavia, the practice has been questioned by environmental groups. Their argument against the use of forest residues for bioenergy is that if the value of cutting the forest increases since more revenue is generated from the sale of biomass products as well as of the primary logs, then more land will be harvested.

When land use change occurs in order to grow an energy crop, the type and proximity of habitats adjacent to it will need consideration. Some crops may attract bird life to feed on the insects or seeds, some may compete with water from neighbouring wetlands, and some may produce self-set wilding plants in nearby fields that will require future eradication.

The intrinsic ecological and historic value of a site should also be assessed prior to any activity related to biomass production occurring. Many countries have clear regulations regarding protection of sites of special historic or scientific interests or identified as conservation reserves. Not all archaeological sites appear on maps as they have not been properly surveyed or recorded, and in some instances are known of only by oral history from the indigenous people. Legal consequences may result from protected habitat or wetland destruction and advice from the local authorities should be sought at an early stage of the process.

Nutrients – and cycling

Continuous large-scale production and harvest of forest plantations and energy crops could reduce soil fertility levels, lead to leaching of nutrients and increased use of agri-chemicals. When any agricultural product is removed from the land some nutrients are extracted with it. This is the case whether the product is milk, wool, meat, cereals, fruit, sugar or wood. A nutrient mass balance can be undertaken to assess the quantities of nutrients removed on an annual basis. Carbon, hydrogen and oxygen are replaced naturally during photosynthesis from water and carbon dioxide, and since it is only the hydrocarbons needed for combustion, then in theory all other elements could be captured and recycled. Where only woody biomass is removed from a forest, there is less nutrient loss than if the leaves, tops, small branches and bark are also utilised

Some attempts have been made to return certain soil minerals, such as phosphates, back to the forest via the recycling of the wood ash from biomass burners. In most cases however this is not feasible and any minerals mined from the soil during crop growth, harvest and removal may need replacing. Regular soil tests enable levels of key minerals to be monitored and, where necessary, for artificial fertilisers, compost or animal manures to be applied to replace them. In this regard energy cropping is no different to traditional agriculture.

Energy cropping has been linked with the land treatment of sewage and industrial sludges and effluents. The nutrients can then be recycled and any possible health concerns from viral and bacterial infections are avoided as the crop is not part of the food chain, although in some countries there are stringent

1. It should be remembered that much of today's agricultural land was once under native forest in many OECD countries. In Australia, USA and New Zealand for example, land clearing practices have only stopped fairly recently.

regulations concerning the land treatment of bio-wastes. However the storage and irrigation costs tend to be prohibitive compared with other forms of sewage or effluent treatment and often only limited volumes are available from sources close enough to cropping land. So it has not become common practice.

In the longer term genetically modified crops grown specifically for energy purposes may become feasible and accepted – perhaps more so for energy crops than for food crops. These could be leguminous based to avoid the need for nitrogenous fertiliser applications. With careful management, recycling of other nutrients may become feasible, as in the manner of today's organic food farms.

Water management

Some energy crops uptake more soil moisture by transpiration than others. Short rotation poplar, willow and eucalyptus plantations for example all have a high water demand when water supplies are readily available but very different tolerances when they are not. This is partly due to their deciduous / non-deciduous nature but it also varies with the specific crop variety and location.

For any crop, a grower should consider the implications of water demand and rainfall when choosing a species and variety, not only on the biomass yield but also, if to be planted extensively, on any downstream water users. In drier regions planting forests has been associated with reducing the volume of groundwater available due to higher levels of evapo-transpiration compared with other crops or native vegetation. A perennial plantation can be designed to minimise negative impacts on water use and develop benefits by such factors as planting in one large block or several smaller blocks, planting blocks sequentially over the years to produce a range of ages for harvesting in sequence, or avoiding planting near bore holes unless the aim is to reduce water contamination.

Crops more suited to arid or dryland regions tend to put their roots down further which can have an impact on soil nutrient levels. Conversely fast-growing tree crops in moist soil can form a dense mat of roots down to a metre or so which enables them to become an effective mechanism for soaking up nutrients and act as a buffer. A possible problem may be the damage by vigorous rooting systems to any field drainage system in place. Another benefit may be that access to machinery, including for harvest during wet seasons, is facilitated by the root mat providing support for the vehicle weight.

How can we obtain more biomass than is currently available?

Improving crop management and yields

Soil types best suited to growing energy crops can be identified and shallow or dry soils avoided as yields are likely to be low and nutrient reserves limiting. Some dryland crops such as *Jatropha* or *Euphorbia* could be suitable for arid conditions but energy yields per hectare are likely to be relatively low, thereby requiring greater harvesting and collection costs.

Irrigation is an option for growing any energy crop to optimise yields. However the cost of the irrigating equipment is usually high, water may be limited and/or costly, high labour inputs can be needed, and the additional yields obtained do not always warrant the extra costs involved. So for energy crops irrigation is not usual, unless it is linked with effluent treatment activities.

For crops that are harvested in the winter, clay soils are particularly prone to structural damage from heavy machinery when wet. Over time this can reduce the yield potential. Crops requiring annual harvesting are therefore not well suited to floodlands, boggy areas or sensitive wetland sites, unless harvested when the soil is frozen as in Scandinavia.

Integrated harvesting

There are usually fixed amounts of available biomass in any given district based on existing agricultural, forestry, municipal and industrial activities. Where some of the biomass is being left on the ground after harvest of the crop, then greater efforts to collect it may be feasible. However this would probably be for a relatively higher cost so integrating the harvesting of biomass with the harvesting of the primary product could be warranted. Skidding whole trees after felling to a central processing site nearby in the forest is an example. The logs are separated from the arisings (the remaining biomass material), thereby giving two product streams that can then be transported separately to sites for further processing. Increased nutrient removal (see Section 1) can be a constraint to taking the arisings for some lower fertile soil types, unless nutrient cycling is achieved.

Breeding of new crop varieties

Most traditional food and fibre crops have been bred for decades to increase their yield and the quality of the product. For example wheat now commonly produces 10t of grain per hectare whereas this was rare only 20 years ago. The variety grown also affects the quality of the bread produced. Similarly oilseed rape (canola) crops have been bred to enhance the yield and quality of oil, though high erucic acid varieties have also been developed for their better properties as an industrial lubricant.

Breeding of crops to maximise their energy content is rare, though varieties of *Salix* (willow), coppiced every 2 – 5 years for biomass, have been selected in order to reduce rust infestations that lower yields. Overall however the breeding and selection of crops grown mainly for energy use is at an early stage of assessment. In the future it could be that genetically modified energy crops can be produced that will be more efficient solar energy collectors (akin to the present C4 plants such as sugarcane and sorghum) and therefore be higher yielding but also require lower inputs of fertilisers, have greater resistance to pest and disease, and be dryland tolerant. If such an ideal new crop is ever produced, the potential for biomass as an energy source would increase significantly.

Growing energy crops

Another way to produce more biomass is to grow it as specialist energy crops. These can be vegetative perennial grasses cut annually or even 2 or 3 times each year, short rotation forests harvested every 5 to 10 years and either replanted or allowed to regrow from the cut stump (coppicing), or annual crops purpose grown for their energy components such as oil, or sugar or straw.

The three major elements that need to be considered when growing energy crops are:

- assessing whether the selected crop will be economically viable to grow, harvest and store under the specific circumstances of the market at that time;
- selecting the most appropriate species and provenance to best match the soil types and climatic conditions; and
- crop management to maximise environmental benefits, minimise any negative impacts and to fit in with existing crop rotations and machine and labour availability.

A grower will select a suitable site for producing an energy crop once a reliable market has been identified and the economic viability confirmed. Site selection will depend on such factors as landscape, visibility, road access, proximity to a bioenergy processing plant, soil type, water availability, disease and pest history, archaeological history, competition for growing other crops and public access. Where a popular view is likely to be blocked or modified, or access to a public right of way reduced, then public resistance to the project will be increased.

Landscapes of specific quality and with conservation values may be under special protection and local policies may apply that inhibit new crop production. Tree crops can also affect visibility of paths and views and impact on people's visual amenity. Straight rows and boundaries for tree plantations for example can have a greater visual impact than planting around the contours. Conversely some plantations may contribute positively to variations in landscape and biodiversity, provide shelter and wind breaks and provide recreational value.

Where a heat demand exists on a farm or for local industry it could make sense to use straw or other crop residues from existing crops. Where no other suitable biomass resource is available, a crop could be grown to meet that purpose. The sale of any surplus biomass by a landowner could generate additional income if there is a market, and also make better use of any under-utilised land.

For all biomass producers, if there is a bioenergy plant nearby within an economic transport distance, the energy crop producer would need to consider how best to become part of the supply chain. This may involve agreeing to a long-term supply contract with transport charges placed on the grower. Therefore the supply radius might be limited to around 50 kms. Forming a co-operative between several growers may assist bulk selling to the plant owner as is common with vegetable and other horticultural products. Alternatively a group of growers could create a local market through a district heat plant or by collaborating on their own power generation plant development. Grants and other subsidy payments may be payable in some regions to assist with such a development.

Why do we need biomass quality standards and fuel specifications to be developed?

Biomass fuels, being of biological origin, are often bulky, have a high moisture content, and are usually of variable and unpredictable quality. For simple combustion systems some variations in the feedstocks are of little consequence within reasonable bounds. However other conversion equipment such as gasifiers, gas engines and other internal combustion engines need fuels to be within stringent specifications if they are to operate satisfactorily and if manufacturers' warranties are to be maintained. Fuel standards are therefore needed to maintain quality within clearly defined specifications.

Techniques for solid fuel upgrading by natural drying, pelletising, briquetting etc. are advancing. For biodiesel, a European standard is in place and other regions are developing theirs. An international bioethanol fuel standard is also being contemplated by the IEA, Advanced Motor Fuel implementing agreement. Fuel consistency may be achieved more easily using the biomass produced from dedicated energy crops than using that produced from a variety of sources such as wood process residues from different sawmills and tree species. Similarly or vegetable oils vary with the oil crop species and also possibly daily where waste oils from restaurants are used.

Most bioenergy conversion plants are usually designed to suit a specific fuel type, but it is likely that the mixture of biomass available and its specific characteristics will change over time. This affects the design of the conversion plant and can even shorten its economic life due to obsolescence if suitable biomass fuels become unavailable.

Method of payment for the biomass resource

A fair means of payment is needed to ensure the producer receives a proper return for supplying good quality and consistent biomass fuel because biomass can vary from truck load to truck load in terms of its dry matter content, energy value, soil contaminants, foreign bodies such as stones or metal parts from the harvester, and source of origin.

It is not sufficient simply to weigh a truck on arrival at a bioenergy plant to assess the weight of biomass and make a payment on that basis. As for a cereal crop, the moisture content will vary from load to load and paying for water is not acceptable. Sampling the biomass material on the truck, analysing it for moisture and other parameters depending on the bioenergy application, making payment on this basis (with penalty deductions for very high moisture, contamination by soil, rocks etc. or even rejecting the load) are options that will need contractual negotiations agreed between the bioenergy plant owners and the landowners or biomass suppliers.

Disease carriers

Untreated biomass material such as the bark component of wood chips, seed contamination of straw residues, or soil contamination of vegetative grass energy crops, can carry a wide range of pathogens and weed seeds. Transporting biomass materials between locations can cause the spread of diseases, pests and weed proliferation so some form of border controls are necessary. Additional concerns arise where biomass in the form of sewage sludge, animal manures, or effluent from meat and other food processing industries is utilised, either for direct combustion as an energy feedstock for biogas plants etc. or indirectly if applied to an energy crop as a form of treatment. Biomass processed into other energy carriers such as pellets, bio-oil, liquid fuels etc. prior to transport off site, and especially for export, can normally overcome any contamination risk, especially where heat is involved in the process.

Certification of the resource and a complete tracking of its origin and history are technically feasible. This would serve to overcome any concerns that local residents might have about the spread of pests. It would also allay any fears the biomass purchaser and user might have about maintaining acceptable resource quality to suit the conversion plant handling and processing systems.

Summary

Most countries and districts have access to one form of biomass supply or another and often in relatively large quantities. Even if classed as a “waste” product, the resource should be assessed as to its sustainable supply over the long term. Biomass feedstocks available as co-products from farms, forests, processing plants and municipal treatment plants are normally limited in the total volume available depending on population, size and scale of the source. Where additional biomass is required to ensure a sufficient supply of fuel exists for a bioenergy conversion plant over the long term, then increased efficiency of conversion processes, multi-feedstock supplies or possibly the more costly option of growing energy crops can be considered. For specific biomass feedstocks to provide vegetable oils for biodiesel or sugar/starch crops for bioethanol, energy corps will also need to be grown. In either case competition for land use, nutrients and water resources then needs evaluation. Where biomass transport and trading are involved, methods to measure and certify the resource are required to ensure that the quality is maintained and the risk of spread of pests and diseases is minimised.

Section 2

Delivering the Biomass and Producing the Energy Carriers

What suitable supply chain and conversion technology developments available now, or in the near future, will enable environmentally acceptable bioenergy products and energy carriers to be generated more efficiently than at present?

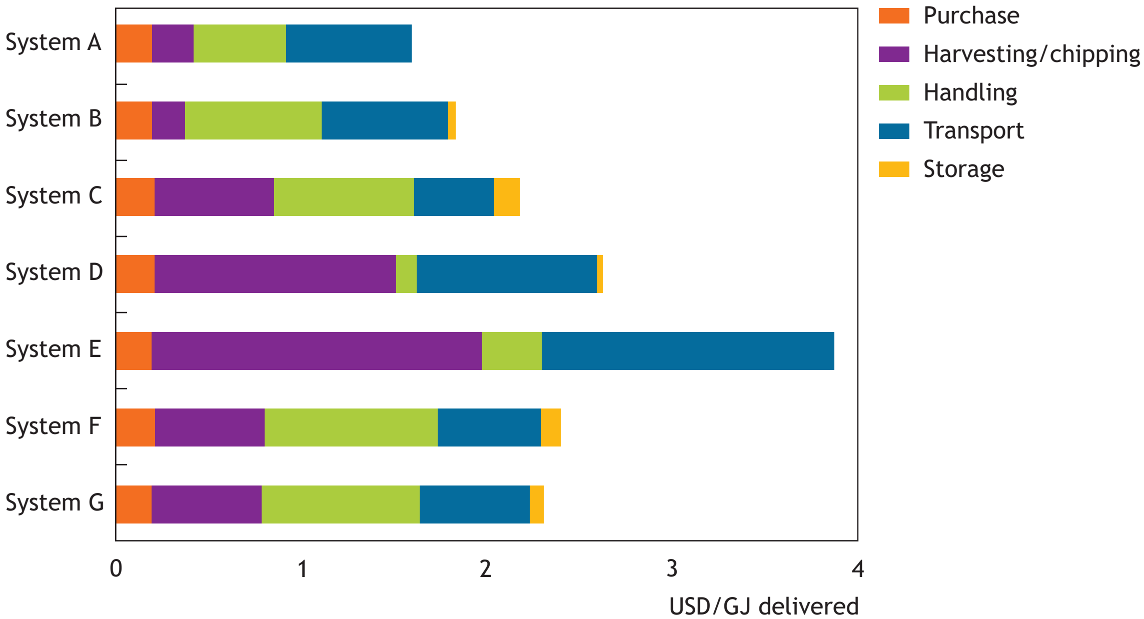
The production of biomass is reasonably well understood and many conversion technologies are mature. However, with the exception of where biomass is produced and used on site, large volumes of biomass usually need to be transported. Some material is already travelling thousands of kilometres to markets such as wood pellets from Canada being shipped to Scandinavia for use in district heating plants and palm oil from Malaysia arriving in Sweden and the Netherlands for biodiesel feedstock. The logistics of transporting, handling and storing the often bulky and variable biomass material for delivery to the bioenergy processing plant gate is a key part of the supply chain that is often overlooked in the early stages of planning. This section covers this topic and links the forms of biomass available to the various conversion plant types. Details of the design, engineering and operation of the numerous bioenergy conversion technologies are not discussed here in detail.

What is the best method to harvest, collect and transport the biomass?

Harvesting and collection

If not collected at the time of harvest using integrated systems (see Section 1), then residues, often widely distributed, will need to be brought to a central location. The method will vary with the type of residue, terrain, machinery availability, location, soil access etc. Whether the biomass comes from forest residues on hill country, straw residues from cereal crops grown on arable land, or the non-edible components of small scale, subsistence farming systems, the relative cost of collection will be considerable. Careful development of a system to minimize machinery use, human effort and energy inputs can have a considerable impact on the cost of the biomass as delivered to the processing plant gate. One study, for example, compared harvest, handling and transport systems for collecting and delivering arisings from a forest to a proposed bioenergy plant in Nelson, New Zealand, 80km away. The model gave a wide range of delivered costs in terms of USD/GJ, purely as a result of the system selected (Figure 11).

Figure 11 • *Delivered costs of forest arisings can vary*



Arisings taken from a single forest site, purchased for USD 4/dry tonne, then delivered 80km over an identical route to a proposed bioenergy processing plant gate, using 7 different options (A-G) for collection and transport systems result in a wide range of costs (Sims, 2003).

Before planting an energy crop the first question a grower should ask is "How will it be harvested?" For some crops such as vegetative grasses, existing agricultural machinery such as hay mowers and balers can be employed for the harvesting operation. Others crops such as short rotation forests will need specialist harvesters to be designed and built which tend to be expensive (Figure 12). Issues such as:

- gaining access in wet weather for heavy machines and trailers;
- leaving areas available for stock-piling the biomass in temporary storage;
- planning the layout of a tree plantation to enable a harvester to gain access and then turn and manoeuvre;
- servicing the harvester with trailers to collect the biomass and keep up with the rate of material harvested;
- assessing the proximity to the roadside for access by transport vehicles; and
- designing the overall system by matching machine capacities in order to convey the biomass between harvesters, trailers, interim storage areas and trucks without costly delays;

all need careful planning at an early stage of project development.

Figure 12 • *Specialist machines to harvest new energy crops*

Equipment designed and manufactured to harvest new crops coppiced Salix, and store the biomass, (here shown as round bales of Salix stems) are relatively expensive in terms of USD/t harvested due to lack of mass production and limited demand.

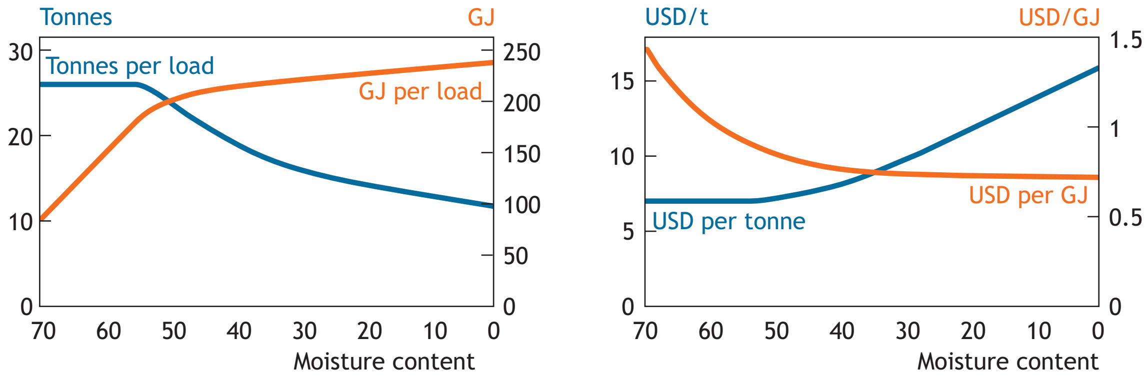
Transport by road and rail

Most forms of biomass and bioenergy carriers tend to have a relatively low energy density per unit of volume (*e.g.* GJ/m^3) or mass (*e.g.* MJ/kg) compared with fossil fuels with the same energy equivalent. For example ethanol has an energy content of ~22 MJ/l whereas gasoline is ~34 MJ/l; air dried woody biomass is around 12-15 GJ/t and sub-bituminous coal around 20-25 GJ/t (low heat values). This often makes handling, storage and transportation more costly per unit of energy carried.

Take for example a truck load of wood chips produced from the branches and tops of a freshly harvested eucalyptus plantation forest. At the time of harvest, trees contain at least 50% water by weight so if the pile in the truck weighs 20 tonnes, 10 t is the "dry matter" of the biomass and 10 t is the water in the biomass. On combustion the load would have an available energy content of around 150GJ. If the truck is now loaded with the same volume of biomass chips, but only chipped after the branches have been left to naturally air dry for a few weeks in the forest down to say 20% moisture content (mc), then the load would now weigh 12.5 t of which the dry matter remains at 10 t but the water now only weighs 2.5 t. The energy content of the load will now be around 175 GJ and is lighter to transport. Being drier, the biomass will also burn more efficiently. If the truck had a 20 t maximum payload capacity, then the original load size would be limited by the weight of the wet chips and not by the volume of the load. If the dry wood chip load carried could have been increased in volume so as to reach the 20 t payload (assuming the truck design allowed a bigger size load, perhaps by adding higher extension sides), then the load would now contain 16 t dry biomass and 4 t water, thus giving an overall energy content of 290 GJ. Hence the transport cost /GJ of available energy would be a lot less as less water is being transported (Figure 13).

Some forest and crop residues are often not competitive because the biomass resource is dispersed over large areas leading to high collection and transport costs. The costs for long distance haulage of bulky biomass will be minimized if the biomass can be sourced from a location where it is already concentrated, such as a sawmill or sugar mill. It can then be converted in the nearby bioenergy plant to more transportable forms of energy carrier if not to be utilised on-site. Where road transport cannot be avoided, due to the low energy density of many solid and liquid forms of biomass, impacts from numerous vehicle movements are inevitable (Table 1).

Figure 13 • *Delivered energy costs vary with moisture content of the biomass*



Weight, and energy per load vary with moisture contents to give different delivered energy costs (USD/t and USD/GJ) of woody biomass when using a 26 tonne maximum payload truck over a cartage distance of 35 km and based on a charge of USD 0.42/t/km.

Table 1 • *Typical scale of operation for various sizes and types of bioenergy plants*

Type of plant	Heat$_{(th)}$ or power$_{(e)}$ capacity ranges, and annual hours of operation.	Biomass fuel required (oven dry tonnes/year)	Vehicle movements for biomass delivery to the plant	Land area required to produce the biomass (% of total within a given radius).
Small heat	100 - 250 kW$_{th}$ 2 000 hr	40 - 60	3 - 5 / yr	1 - 3% within 1 km radius
Large heat	250kW$_{th}$ – 1 MW$_{th}$ 3 000 hr	100 - 1200	10 - 140 / yr	5 - 10% within 2 km radius
Small CHP	500 kW$_e$ – 2 MW$_e$ 4 000 hr	1 000 - 5 000	150 - 500 / yr	1 - 3% within 5 km radius
Medium CHP	5 – 10 MW$_e$ 5 000 hr	30 000 - 60 000	5 - 10 / day	5 - 10% within 10 km radius
Large power plant	20 – 30 MW$_e$ 7 000 hr	90 000 - 150 000	25 - 50 / day and night	2 - 5% within 50 km radius

Transport and land use requirements to meet annual biomass demands when operating at various capacity factors. Biomass yields when produced from forest arisings, agricultural residues or purpose grown energy crops, are assumed at around 5 - 10 oven dry tonnes per hectare annually.

The forest and sugar industries have largely overcome the large-scale transport problems of bulky feedstocks many years ago. Sugar processing plants for example typically handle around 300 000 t of sugarcane billets during the 6- to 7-month harvesting season and as a result need an efficient transport system. Some sugar mills in Queensland, Australia for example rely on road trucks that can automatically hitch and detach several trailer bins towed behind them, whereas other mills have built a network of narrow gauge railway tracks to connect the growing areas directly with the mill (Figure 14).

Figure 14 • *Transporting sugarcane to the mill is well established*

A tractor high-rise tipping trailer used to collect billets by running alongside a sugarcane harvester then transferring the load to bins on a mini-rail transport system for delivery to the sugar mill.

The collection and transport of biomass can result in increased use of vehicles, higher local air emissions from their exhausts, and greater wear and tear on the road infrastructure. Who should pay for the extra costs is difficult to determine. Where the roads are maintained by higher charges placed on local ratepayers, most of whom receive little benefit from the passing of heavy trucks through their district, the problem is hard to resolve.

Moisture content reduction

Drying of the biomass is a key part of the supply chain process. When combusting wet forms of biomass such as freshly harvested woody biomass, the heat required to raise the temperature and evaporate off the moisture has to be generated by the wood itself. Hence the thermal efficiency of the overall system will be reduced when using fuels of higher moisture content. When quoting the heat (or energy) values of a fuel, clarification is needed between low and high (or net and gross) values. The high value is based on the energy content of the fuel but the low value, as used in this report, is more realistic as it allows for the losses based on the moisture content (mc) and combustion of the hydrogen content (Table 2).

Heat lost in the system is also directly attributable to the moisture content of the fuel which directly affects the overall efficiency. These losses will vary from around 2% of the total heat input when the fuel is air dry at around 10-15% mc, up to 15% losses when the fuel used is above 50% mc. So the drier the biomass fuel the better. In addition losses in thermal efficiency occur due to unburned fuel being carried into the ash (possibly 0.5% loss) and surface heat loss from the actual plant of around 3-5% which varies with the plant design and the area and temperature of the external radiating surfaces.

In addition to the original mc of the biomass feedstock, biomass contains a proportion of hydrogen atoms that, during the combustion/oxidation process, chemically react to form water. The heat required to raise the temperature and evaporate this extra water also becomes unavailable to the system and has a similar effect on reducing the overall heat recovery efficiency. The effect on the combustion system efficiency from both the free moisture and that formed by combustion of the hydrogen can be calculated (Table 2).

Table 2 • *Typical heat losses during combustion*

Form of the woody biomass	Moisture content (% wet basis)	Total weight of biomass (kg)	Weight of water present (kg)	Heat to evaporate moisture (MJ)	Heat to evaporate H_2O from hydrogen combustion (MJ)	LHV of the 2 000cm^3 volume (MJ)	LHV/kg of wet wood (MJ/kg)
Freshly harvested green wood	60	2.5	1.5	3.73	1.39	14.78	5.9
Drying for 1-2 weeks post harvest	50	2.0	1.0	2.57	1.39	15.94	8.0
Sawmill residues	40	1.67	0.67	1.72	1.39	16.79	10.0
Demolition timber / pallets	30	1.43	0.43	1.10	1.39	17.41	12.2
Air dried biomass	20	1.25	0.25	0.64	1.39	17.87	14.3
Wood processing off-cuts	10	1.11	0.11	0.28	1.39	18.23	16.4
Oven dry wood for comparison	0	1.0	0	0	1.39	18.51	18.5

A 2 000 cm^3 piece of wood with basic density of 500 kg/m^3 and high heat value (HHV) of 19.9 MJ/kg dry weight is combusted. The moisture content of the biomass fuel and combustion of the hydrogen contained in the fuel affects the final useful heat energy available (lower heat value LHV).

Since traditional heat plants (furnaces or boilers) are usually designed to maintain sufficiently high exhaust gas temperatures to avoid condensation in the flue stack of the combustion plant, this heat is usually not recoverable. However condensing steam boilers and turbines gain extra efficiency by condensing the water vapour and retrieving much of the latent heat of evaporation available by so doing. Fans are then often used to force out the exhaust air and hence avoid tars condensing in the flue. Thus higher conversion efficiencies are obtained for a relatively small extra capital investment. Such technology is available over a range of boiler sizes from domestic to >5MW.

Improving the collection and storage of residues

The logistics of supplying a bioenergy plant with sufficient volumes of biomass from a number of sources at suitable quality specifications and possibly all year round, are complex. Storage of solid biomass is usually outdoors and possibly on concrete pads if located close to the conversion plant. Forestry and agricultural residues can also be stored in the forest on landings or on the farm until needed. Then they can be collected and delivered directly to the conversion plant on demand. At times this requires considerable logistics to ensure only a few days of supply are available on-site but that the risk of non-supply at any time is low.

Losses of dry matter, and hence of energy content, commonly occur during the harvest transport and storage process. This can either be from physical losses of the biomass material in the field during the harvest operation or dropping off a truck, or by the reduction of dry matter of biomass material which occurs in storage over time as a result of respiration processes and as the product deteriorates. Dry matter loss is normally reduced over time if the moisture content of the biomass can be lowered or oxygen can be excluded in order to constrain pathological action. Conserving green crops by natural drying (such as pasture hay) or by ensiling it for use later in the season (perhaps as green feedstock for biogas plants), are good examples.

The storage of biomass is often necessary due to its seasonal production versus the need to produce bioenergy all year round. Therefore to provide a constant and regular supply of fuel for the plant requires either storage or multi-feedstocks to be used, both of which tend to add cost to the system. Since biomass tends to have relatively low energy density (whether as a solid, liquid or gas), and is organic, then the storage of large volumes can be costly. For example biogas needs either large plastic or steel storage tanks or to be compressed and stored in cylinders, both being expensive options. Therefore matching the biogas production rate to the demand is the more usual approach.

For dry biomass material such as straw the risk of fire when stored in large piles is high, and Greener materials such as bagasse or wood chips are also risky being prone to spontaneous combustion when stored in piles due to bacterial action causing heat build-up (similar to composting). Regular stirring of the piles to dissipate the heat is the usual solution.

Some plant managers employ a contractor to be responsible for providing the fuel supply within certain specified parameters relating to fuel quality and moisture content. For example where a number of biomass types and sources are used, the biomass can be comminuted (broken into small pieces) on delivery then stored in piles according to the appropriate moisture content. The yard operator can then select material from each of the piles to try and maintain a mix entering the plant that has a fairly constant average moisture content to best suit the design of combustion or gasification system (Figure 15).

Figure 15 • *Delivered biomass stockpiled according to moisture content*

Mixing by the loader operator of the plant conveyor maintains the optimum feedstock moisture content to match the combustion system design.

Figure 16 • *Compacted and tied bales of forest residues*

Bales are produced for easy transport by road or rail to the bioenergy plant - the one shown here being the largest in the world, in Finland.
Source: John Deere Company; www.timberjack.com

Innovative supply chain processes for delivering forest arisings to bioenergy plants have been developed to overcome many of the logistical problems identified (Figure 16).

Handling equipment

The physical handling of biomass fuels during collection or at a processing plant can be challenging to conveying equipment designers, particularly for solid biomass. It has even led to the early failure of entire bioenergy projects. Even the pumping of slurries, effluent and manure, although common practice, still leads to problems due to worn pumps, foreign bodies, corrosion of pipes, restrictions at bends etc. Wherever a pipe is used, invariably at some stage it will become blocked.

Biomass fuels tend to vary with density, moisture content and particle size (some even being stringy in nature) and can also be corrosive. Therefore biomass fuel handling equipment is often a difficult part of a plant to adequately design, maintain and operate. Augers and pneumatic conveyors tend to block whereas open, flat bed conveyors are limited to the steepness of the gradient and can also malfunction when the feedstock characteristics vary from the normal. Overcoming potential problems by improved conveyor design and the use of non-corroding materials is feasible, but then higher costs for such better quality equipment can become a barrier.

What forms of bioenergy carriers can best be generated using the range of conversion plant designs available?

Raw biomass materials can be broadly classified into wet or dry resources as well as liquids or solids. Biomass with a high moisture content is usually preferred for anaerobic digestion, pyrolysis or for biofuel production whereas dry solid biomass is preferred for combustion or gasification. Bioenergy carriers can range from a simple firewood log for domestic heating to a highly refined liquid transport fuel for blending in large volumes. Different biomass products therefore suit different situations. Specific objectives for utilizing biomass are governed by the quantity, quality and cost of the feedstock available, location of the consumers, type and value of the energy services required, and any specific co-products or benefits that result.

To fully utilise the capital investment costs of a bioenergy plant, just as for any other investment, operating it 24 hours a day, every day, other than the down-time needed for occasional maintenance, is the ideal business case. This necessitates having reliable suppliers of the feedstock.

To enable any available biomass resource to be matched with the end use energy carrier required (heat, electricity or transport fuels) the correct selection of conversion technologies is required. Using Figure 5, starting with the available biomass resource then following the alternative lines up the chart to the chosen energy carrier at the top will help identify the conversion technology options possible. Thus if a coconut processing company wished to generate electricity on-site, it could either use the coconut shell residues for direct combustion to produce steam to power an engine or a turbine, or use a gasifier and gas engine, or opt to go via the pyrolysis route to produce bio-oil for combustion to raise steam. The costs and other barriers associated with each optional pathway would then need to be assessed in detail to identify the most profitable and practical option.

Bioenergy conversion technologies

A wide range of conversion technologies are under continuous development to produce bioenergy carriers for both small and large scale applications including for heat – though are not described here in detail. The use of biomass for cogeneration (combined heat and power) and industrial, domestic and district heating continues to expand. Combustion of biomass to provide heat, including for steam turbine power generation at the large to medium scale remains the state of the art. At the smaller scale, biomass pellet and briquette combustion systems mainly used for domestic and industrial heat supply are experiencing growing demand in some OECD countries due mainly to their convenience. They also provide good potential for developing countries to export their surplus biomass as the pellets are portable, flowable, have consistent quality with a low moisture content, relatively high energy density, can be stored (if sheltered from the weather) and can be manufactured from a range of feedstocks (see for example www.WorldBioenergy.se, 2006).

Advancing technologies include biomass integrated gasification combined cycle (BIGCC) systems, co-firing (with coal or gas), pyrolysis and second generation biofuels. Many are close to commercial maturity but are awaiting further technical breakthroughs to increase the process efficiency, followed by large scale demonstrations to help reduce the risks and further bring down the costs. Second generation biofuels for example may one day use biochemical technologies to convert the cellulose to sugars that in turn can be converted to bioethanol, biodiesel, di-methyl ester, hydrogen and chemical intermediates in large scale bio-refineries. In addition biochemical and thermo-chemical synthesis processes could be integrated in a single bio-refinery such that the biomass carbohydrate fraction is coverted to ethanol and the lignin-rich residue gasified and used to produce heat, electricity and/or fuels, thus greatly increasing the overall system efficiency to 70-80%. Both concepts however remain some way off reaching the commercial scale, despite decades of research investment

Co-combustion and co-firing

Biomass can be combined with fossil fuel technologies (directly mixed or indirectly in separate streams) by co-firing solid biomass particles with coal; mixing synthesis gas, landfill gas or biogas with natural gas prior to combustion; blending diesel with biodiesel and gasoline with bioethanol; and using flexible fuel engines in vehicles. There has been rapid progress in the development of the co-utilisation of solid biomass materials in coal-fired boiler plants. Worldwide more than 150 coal-fired power plants in the range 50-700 MWe have operational experience of co-firing with woody biomass or wastes, at least on a trial basis. Commercially significant lignites, bituminous and sub-bituminous coals, anthracites, and petroleum coke have all been co-fired with a very wide range of biomass material up to 15% (by energy) content, including herbaceous and woody materials, wet and dry agricultural residues and energy crops. This experience has shown how the technical risks associated with co-firing in different types of coal-fired power plants can be reduced to an acceptable level through proper selection of the type of biomass (to avoid ash clinkering problems etc) and choosing the most suitable fuel mixing and co-firing technology. It is a relatively low cost and low risk means of adding biomass capacity, particularly in economies in transition and developing countries where old and in efficient coal-fired plants remain prevalent.

Improved insight into fundamental aspects relating to combustion performance and ash behaviour of various biomass feedstocks when used in a blend with coal, or indeed alone, could lead to further increases in plant reliability and efficiency. Overall emission levels and specific investment costs can be reduced as a result but a better understanding of the combustion of more difficult biomass fuels with high alkali content such as cereal straw is needed.

Synthesis gas

Gasification of biomass to synthesis (producer) gas consisting mainly of CO and H_2, has a relatively high overall conversion efficiency (40-50%) when used to generate electricity through a gas turbine (or around 30% through a gas engine). The gas produced can also be used as feedstock for a range of liquid biofuels based on the Fischer-Tropsch process. Development of efficient BIGCC systems is nearing commercial realization but the challenges of gas clean-up remain. Several pilot and demonstration projects have been evaluated with varying degrees of success.

Biogas from anaerobic digestion

Recovery of methane from modern biogas plants following anaerobic digestion of the wet biomass feedstock (animal, human, food and organic wastes and green crops) has increased in recent years and more than 4 500 installations (including landfill gas recovery plants), were operating in Europe alone in 2002. The total market potential by 2020 has been estimated to be nearly ten times the current energy production from biogas of over 90PJ /year. Biogas can be used for production of electricity and/or heat. It can also be fed into natural gas grids or distributed to filling stations for use in dedicated or dual gas-fuelled vehicles, but for this application the biogas first requires scrubbing to remove any carbon dioxide and hydrogen sulphide present.

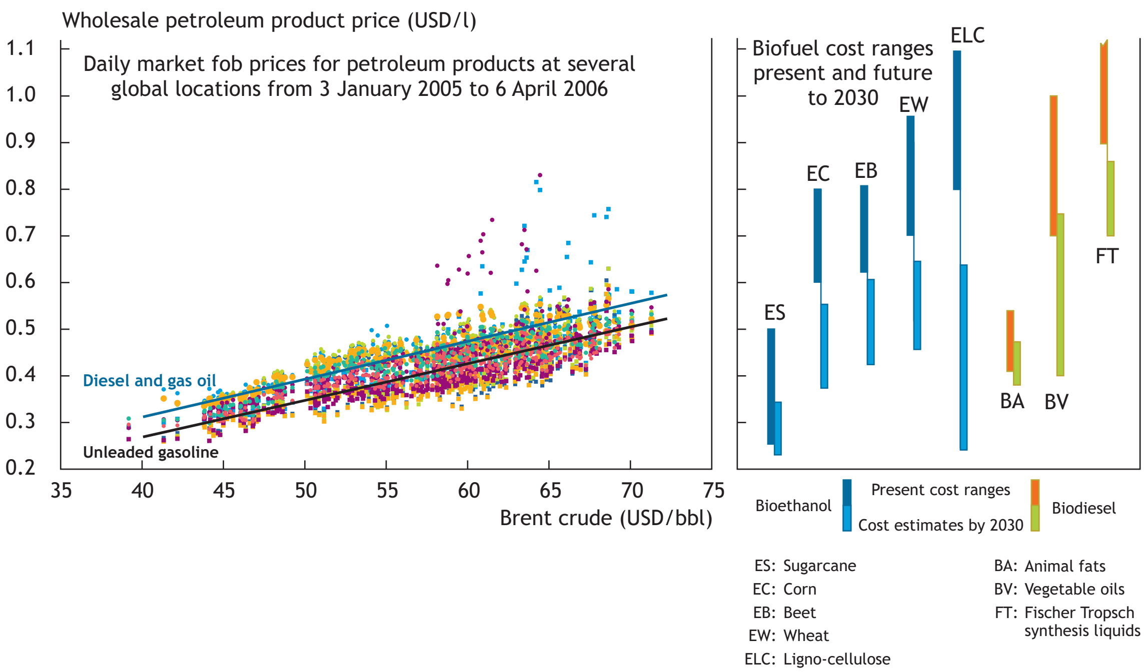
Biofuels for transport

OECD countries value biofuels mainly as a means of reducing greenhouse gases, meeting clean air policies and achieving greater energy supply security by reducing foreign oil dependence. Developing countries also consider biofuels to be a means of stimulating rural development, creating jobs, and saving foreign exchange. Concerns about conventional oil availability, security of supply and fluctuating prices in all regions have increased the interest in biofuels for transport since they are seen as a near-term alternative. Other options of unconventional oils and coal-to-liquids and gas-to-liquid processes usually produce higher CO_2 emissions per kilometre travelled. Hydrogen, as a transport fuel, will probably only become available in the medium to long term.

Global biofuel consumption in 2002 was around 15 billion litres but by 2005 this had tripled. Around 38 billion litres of bioethanol (1.2 EJ) were produced mainly in Brazil, USA and China for use in blends normally up to 10% ethanol but up to 85% in flex-fuel engines (or even 100% hydrous ethanol in Brazilian designs). In addition over 3 billion litres of biodiesel were produced, mostly in Europe.

Commercial bioethanol production costs, without any agricultural subsidies, direct grants or other government incentives included, currently range from USD 0.25 per litre of gasoline equivalent (lge), (sugarcane, Brazil) to USD 0.80/lge (sugar beet, UK) with corn ethanol around USD 0.60/lge (USA) and ligno-cellulosic ethanol from pilot scale plants claimed to be between USD 0.80 to 1.00/lge. Biodiesel costs range from USD 0.42/l (animal fats, New Zealand) to USD 0.90/l (oilseed rape, Europe; soybean, USA; palm oil; Malaysia) (Figure 17). Technology development and larger scale plants could lower production costs of bioethanol by 2030 to USD 0.23-0.65/lge and biodiesel to USD 0.40-0.75/lge.

Figure 17 • *Biofuels costs compared with diesel and gasoline wholesale prices*



Daily wholesale gasoline and diesel prices (USD/l free on board) in 12 locations versus the crude oil price compared with the production cost ranges for biofuels without any government support schemes, both now and as anticipated by 2030.

Ethanol from sugar cane can compete when the crude oil price is around USD 40-50 /bbl and biodiesel from animal fats around USD 60-70 /bbl without any government support measures. Without support, other biofuels will only compete when oil is well above USD 70/bbl until the production costs can be significantly reduced as a result of returns on current and future RD&D investment; by plant scale-up to the fully commercial size; and through consequent learning experience. Otherwise biofuels will continue to be dependent on various government interventions such as agricultural subsidies, trade barriers and excise tax exemptions.

Emissions and odours

Combustion of all fuel types results in atmospheric emissions whether from the exhaust pipe of a vehicle or the flue stack of a thermal generation or heating plant. Overall the emissions from biomass and biofuel combustion tend to be lower and less noxious than from their fossil fuel equivalents since they are relatively lower in sulphur and nitrogen content. However, emissions vary widely with the biomass source, fuel characteristics, combustion temperature, etc. so specific monitoring and analysis may be required.

Where landfills, effluents, animal manures, wet process wastes, or sewage treatment plants are involved as "waste-to-energy" projects, odour pollution can be a nuisance and may need controlling. Conversely, well designed, anaerobic digestion plants can reduce the odour from animal waste feedstocks with the residual odourless effluent able to be returned to the land as a nutrient source.

Local regulations will vary regarding any emissions to air (including fly ash, dioxins, carbon monoxide, carbon dioxide, sulphur dioxide, nitrous oxides, particulates, dust), so early consultation with the local authority will be necessary. The height of chimney needed will be determined by the nature of the plume (as determined by modelling techniques), topography, proximity to nearby buildings and their height, and plume content treatment. Consultation with nearby residents will be needed on the balance between mitigating for the contents of the plume versus the height of chimney and its visual impact. A resource consent often involves regular monitoring of emissions (either automatically or manually) to ensure that any conditions imposed on a bioenergy plant are being met. The records are often put into the public domain. The cost for this monitoring service is normally borne by the plant operator and a plant can be shut down if emissions levels are exceeded.

Emissions of any liquid effluents or leachates from biogas or biofuel plants could have an impact on water courses, ground water and soils. These will need consideration of possible treatment and/or disposal to land or water as will, the disposal of the ash coming from combustion plants.

Ash disposal

Ash resulting from combustion or gasification of biomass is either collected as "bottom ash" from the furnace or, in larger plants, as the "fly ash" by separation from the exhaust gases in the flue. Straw and vegetative grasses tend to have large volumes of ash (8-12% of the original dry weight) than woody biomass (1-5%). Gasification can produce less ash from the same feedstock by comparison with its combustion.

The ash can have a value as a low nitrate fertiliser or as a raw material in the brick and cement industries. The nature of the ash, access to nearby land, soil types, and existing soil nutrient levels will determine if the practice of returning it to the land may be feasible in order to recycle some of the nutrients and trace elements and to use it for soil conditioning. Ash contents vary with the source of biomass and can often include a concentration of heavy metals if the biomass was co-fired with coal or originated from soils on land carrying a treatment process where sewage or other liquid wastes and soil conditioners are applied. This can add to the complexity of the disposal process. An assessment of the ash content should be made. Where there is no practical use for the ash, disposal to landfill is usually the preferred option. Handling and disposal procedures are often regulated so local requirements will need to be met.

Summary

Harvesting the biomass resource and delivering it to the bioenergy plant is often a costly logistical exercise not always planned for in detail when a biomass project is contemplated. The biomass fuel needs to be of suitable and consistent quality, available when required (usually all year round), and have a low USD/GJ price delivered to the plant gate.

A large range of bioenergy conversion technologies exist and selection is dependent on the biomass resource available and the energy carrier required. Production costs vary with scale of plant and location as well as with the delivered costs for the biomass fuel. These range from being negative where a waste disposal cost is avoided, or being relatively expensive compared with fossil fuel alternatives where a purpose grown energy crop is produced on good arable land having a high opportunity cost.

Section 3

Overcoming Barriers and Encouraging Benefits

What impacts will an increasing use of biomass have on the environment, on water supplies, and on social issues such as employment, health, equity and development? If not beneficial for the local community, how can they be mitigated?
How can an environmental impact assessment best be prepared in order to gain project planning approval?

Developing a bioenergy project is not without its challenges in order to appease all the stakeholders involved.

- Environmental groups are sensitive to bioenergy projects and will only accept the use of biomass if defined and certified as "sustainably produced".
- Biomass producers want good returns per hectare for collecting or growing the resource (which therefore has to compete with other land uses) or for collecting and storing it if produced as a waste product from another process. (However as soon as a by-product material is seen to have a value it is no longer seen as a "waste" and the purchase price will inevitably increase).
- Bioenergy plant developers want the security of long-term fuel supply contracts in place before proceeding further to invest in the plant.
- Equipment manufacturers want their products selected so design should ensure improved thermal efficiencies, better controls and reliable feedstock handling in order to gain better returns and a larger share of the market. Efficient plant operation necessitates the biomass fuel supply reaching the consistent quality standard for which the plant was designed.
- Project financiers want to reduce the risks of investment by having heat or power purchase agreements in place, along with fuel supply contracts, and perhaps green pricing options.
- Power plant operators want quality biomass fuel delivered consistently all year round to an agreed prescribed set of standards and characteristics. Installation of back-up fuel combustion facilities (such as for LPG or natural gas) can offset the risks of non-delivery.

- Competing markets may wish to secure the biomass resource for other end uses such as garden mulch, pulp, fibre board manufacture, transport biofuel production, chemical plant feedstock etc.
- Communities, particularly in rural areas where most biomass plants will be located, want secure and long-term employment, independence, and some control over local resources.
- Immediate neighbours want their lives to continue as normal without additional noise, traffic, dust etc.

What are the barriers – and the possible means to overcome them?

Removing barriers to bioenergy project implementation is a challenge for developers and policy makers wishing to see more projects up and running. For some technologies such as landfill gas plants, the co-benefits are evident and rapid deployment has consequently occurred since the 1980s with little government intervention. The more rapid deployment of other bioenergy technologies where all the benefits are less evident could be achieved by offering a number of incentives.

Sustainable development

Any utilisation of biomass for bioenergy must be planned within the context of national policies relating to economic growth and sustainable development. In IEA member countries this will be through endeavouring to meet the needs for energy services by the present generation without compromising the ability of future generations to meet their own needs. For the least developing countries, the increased deployment of modern bioenergy as a reliable and affordable source of energy could be part of the solution to overcoming their current constraints concerning GDP growth. In all cases, production and use of biomass should be sustainable in terms of the social, environmental and economic perspectives (Section 1).

Economic

On the one hand a biomass producer will not embark on a business venture without a definite market for the biomass. On the other hand a bioenergy developer will not invest in constructing a bioenergy plant without first securing a biomass fuel supply over the long term. A reliable market for the heat, power or biofuels to be produced also needs to be identified and purchase agreements signed. A project will only become "bankable" once these issues have been resolved. An investor or banker will need to have confidence that all aspects of the project are well defined and contracts and warranties are all in place because a plant is likely to require a substantial financial commitment over a relatively long period before a return on investment results.

Many bioenergy projects are technically feasible but investments do not proceed because other forms of energy appear to be more cost competitive. A significant barrier results where the relatively high costs for bioheat, biopower or biofuels cannot compete on purely economic terms with fossil fuels used to provide the same amount of useful energy. The concept of providing a "level playing field" to enable true cost comparisons to be made that include all subsidies, co-benefits etc is often suggested but rarely achieved in practice.

Many investors still perceive the risks of bioenergy projects to be significant and would often prefer to invest in other renewable or conventional fossil fuel energy projects. Effective risk management and establishment of demonstration plants could help to reduce these perceived barriers and thereby lead to an increase in the number of willing investors. This would result in more competitive financing opportunities.

Investors often tend to seek a short payback period of 2-4 years which favours conversion plants with low capital cost, albeit usually with a high fuel cost. Large bioenergy heat and power plants usually have a relatively high capital cost of around USD 1300 - 2 500/kW compared to gas or coal plants at around USD 900 - 2 000/kW. The granting of increased depreciation rates would help to reduce this high capital cost barrier and help encourage potential investors to favour bioenergy plants (see below).

At the smaller scale, for individual small business investors such as a sawmiller building a wood-fired timber drying kiln, or a pig farmer constructing a biogas plant (Figure 18), the installation of a bioenergy facility on their property may be one of the largest single capital investments that they will make. The ability to raise the capital funds needed for the investment may be beyond their means. Such businesses often possess basic, hands on, engineering skills so tend to purchase, modify and install second hand plant and equipment. However this is usually less efficient, requires higher labour inputs, and involves more maintenance such that investment in new, efficient, low labour intensity plants would be a better economic proposition in the longer term, assuming sufficient capital was available. However a poor understanding of the project risks by bank managers and investors can lead to difficulty obtaining finance and a deficit of capital needed to build the project is the result.

Relatively high transaction costs are also commonly experienced for the development of smaller scale plants since it costs a similar amount of time, effort and money to secure USD 2M finance for say a 1 to 2 MW project as it does to secure USD 200M for a 50 - 100MW project.

Figure 18 • *Anaerobic digestion plant and biogas storage tank*

This 4 000 sow pig farm in South England using two gas engines (housed in the closed shed) to provide electricity for use on the farm as well as low grade heat for drying lucerne for horse feed as an ancillary farm operation.

Economic risks of using biomass for power generation in the electricity market are high due to competitive costs from coal- and gas-fired plants and from other renewable energy plants including hydro, geothermal and wind. Similar competition exists in the heat market between biomass, gas and coal. Delivered forest residues for example can cost double, in terms of USD/GJ, for coal delivered to the plant gate, yet the savings in CO_2 emissions and other environmental costs are rarely accounted for. Therefore bankers and financiers should be invited to become more involved during the project development process in order to fully understand the issues. The problems of low confidence in financial projections and possible insufficient debt service coverage could then be explored. Financial investors specialising in renewable energy projects are now appearing, as are insurance companies willing to offer specialist cover for the many risks that a renewable energy project and its development might incur. This should assist the deployment of bioenergy.

Other economic barriers result from the deregulation of the power industry in many countries. In some cases this has made it more difficult for renewable energy projects, including bioenergy ones, to enter the market due to the resulting lower wholesale electricity price. In addition deregulation has resulted in low investment in infrastructure by the industry. This however means that some independent power producers may now be able to benefit by developing a bioenergy project where it has become more competitive to do so, perhaps due to its location on a weak part of the distribution grid. The uptake of embedded, distributed energy systems could help minimise transmission costs and losses, increase rural energy security, and enable smaller scale bioenergy plants to be built, possibly more suited to CHP systems than stand-alone power plants.

Taxation

Investment costs for bioenergy plants can be partly overcome by increasing the depreciation rates on plant and equipment for tax purposes. This would reduce the investment payback period, increase the return on investment, and hence help to alleviate the capital investment and long payback period barriers that bioenergy plants currently face. For example, in theory biomass boilers might have a useful life of say 25 years, yet during that period it is quite possible that the biomass fuel supplies will change and obsolescence will therefore occur. A shorter operating life therefore results and tax depreciation assessments could reflect this.

For biofuels, reducing excise taxes, especially if the overall benefits can be shown to offset the loss in government revenue, may be applied to the use of fuels with a biofuel component as is already the case for biodiesel in Germany and bioethanol in France.

Technical experience

When it comes to building the plant, higher costs than anticipated usually occur in the early stages of development. For new plant designs and immature technologies as are often found with bioenergy plants today, the risks can be partly mitigated for by good design and by long term (5- to 10-year) warranties from equipment manufacturers. Construction risks can be overcome by having a fixed contract price, and by purchasing insurance cover against delays and liability.

Most technologies move down an experience curve based on “learning by doing”. The many pitfalls and problems that usually arise when building a prototype plant can be partly overcome when building a second plant. As more experience is gained fewer problems occur and shortcuts can also be taken. In general terms, for every doubling of total installed capacity of an energy technology, such as a biodiesel manufacturing plant, the capital costs will be reduced by around 20%.

Public image

Barriers to bioenergy deployment include public concerns relating to:

- the perception of burning biomass as “dirty” as a result of assumed high atmospheric emissions and using out-dated technologies;
- the need to grow large-scale monocultures, possibly genetically modified, and negatively impacting on landscape and biodiversity;
- the impact on land use diversification and biodiversity by having to secure long-term biomass fuel supplies;
- the clearing of native forests to plant perennial energy crops such as oil palms and eucalyptus trees (see Section 1);
- increased transport activities due to the relatively low energy density of many forms of biomass (see Section 2);
- the relatively high demand for water and nutrients by some crops – although possibly no higher than for traditional food and fibre crops;
- the high transport requirements from the need to collect biomass feedstocks that are widespread, or to import them, in order to achieve economies of scale for commercial conversion plants; and
- obtaining resource and planning consents with minimum consultation due to time pressures to negotiate financing and contractual arrangements.

Before planning consents can be obtained for a bioenergy project, an environmental impact assessment is often needed in which many of these concerns can be addressed.

Education and comprehension

Business managers. Lack of available information on a proposed bioenergy conversion plant creates barriers, as do uncertainties of what are often deemed to be “new technologies” by those making business decisions. Relatively few senior business managers possess good technical information about their existing plant and its energy requirements, never mind what any other technical options might be possible. Larger businesses can afford to employ specialist energy managers but even they may not be aware of all the bioenergy opportunities. Commitment to energy saving or climate change mitigation is often lacking since energy inputs into many businesses are only a small percentage of annual total costs. However, as energy prices fluctuate and future energy security concerns grow, the interest in energy efficiency and alternative supply options such as bioenergy become more apparent.

Plant engineers. The time available for a plant manager or company engineer to become more familiar with a range of possible bioenergy options that could meet their energy demands is often constrained. Even when an investment decision is made to proceed to build an on-site heat or power plant, selection of the design and ancillary equipment for a specific project is largely based on the marketing effectiveness of the manufacturers rather than on a thorough investigation of the alternatives. To avoid unsuitable or poorly designed bioenergy plants being widely sold, which could give the industry a poor image, there is a need to research and publish information that will assist potential investors to make appropriate equipment selections.

Investors. People proposing to invest in bioenergy plants also sometimes lack key relevant information and may rely on their own knowledge often derived from magazines, out-dated publications or gleaned by word of mouth. To reduce their investment risk they could opt to seek and pay for quality advice.

Communities. People living in close proximity to a proposed plant may well lack the appropriate information regarding its possible impacts. Where a novel crop is to be grown and a bioenergy plant established, a high level of public interest will naturally result. This will especially be the case if the proposed project can also provide opportunity for local recreational activity. Providing a visitor information centre, or public wildlife area with educational potential, could be an additional incentive for securing a resource consent from the local authority (and possibly earn extra revenue for the land owner). In addition the bioenergy plant itself could become a visitor attraction to provide educational opportunities as well as additional revenue.

Water use – quotas/licences

Normally a fast growing energy crop requires good supplies of water if its yield is not to be adversely affected. Irrigation of energy crops is costly and often not affordable given the value of the products. More frequently though a forest energy crop can interrupt the natural water supply to downstream regions and hence impact on the growth of other crops. Growers and local land management authorities should therefore always consider the possible impacts on water demand when selecting and approving land use change on a specific site.

Water demand for new crops can be a major constraint in some dry and arid regions. The demand for water will vary with the choice of species (*Eucalyptus* being greater than *Pinus* for example) and on the varieties selected for planting. In some circumstances the planting of short rotation coppice crops and forest crops can be utilised to absorb water and excess nutrients as a land remediation process. For example willow can be utilised to help drain wetlands and oil mallee crops can be grown to control dryland salinity (Figure 9). In such instances the biomass can possibly be harvested as a secondary product, the main objective from planting the trees being to gain improvements to the land for more productive uses.

Another related factor to consider is where forest and crop residues are removed from the land for biomass purposes but increased risk of soil erosion by wind or high rainfall events could result. In the North American prairies for example, cereal straw is incorporated into the top soil after harvest as a protection against wind erosion to which these lands are prone.

Supply contracts – long term

Lack of certainty of fuel supply availability at an acceptable cost over a long term can be a significant barrier to achieving increased deployment of many bioenergy projects. Most food and fibre crops are grown and sold on an annual basis, often for widely varying commodity prices. So there may be a reticence by growers at making a commitment to continue to grow specific energy crops over a long period. The developers of a large plant may therefore take overall responsibility for obtaining the required biomass, either by securing long-term contracts well in advance or producing their own biomass supplies. If using local landowners to grow the biomass crops under contract, they will need to specify the form in which the biomass feedstock is required and even have significant input into how the crop is managed, harvested, stored and transported. This is not a new concept and sequential harvesting dates have long been the arrangement between growers and processors of canned and frozen vegetables and fruit in order to ensure that adequate quality is maintained.

Fuel supply risks from competing markets for the biomass can be overcome by negotiation of appropriate contracts and forward sales agreements. However many biomass fuel suppliers are farmers who are not used to long-term contracts.

For a large plant a fuel supply merchant could be contracted to provide guaranteed fuel supplies with a penalty clause for non-delivery and hence transfer the risk. In addition incentives (or penalties) could be given to fuel suppliers and growers to provide consistent fuel quality as delivered to the conversion plant to further reduce the risks. All eventualities (such as the death or insolvency of a supplier) need to be covered since access to fuel by the plant operators will be required whatever the circumstances.

Energy ratios

The energy balance of a bioenergy project is not always favourable, though this is particularly the case for some biofuels produced from annual energy crops, where at times energy unit inputs into the overall system can be similar to, or even exceed, the energy unit outputs in the bioenergy product. In contrast, for biomass produced from perennial crops used for heat, the useful energy output can be at least 10 – 20 times greater than the energy input. For second generation bioethanol, the promising development of enzymatic hydrolysis of ligno-cellulose should have a more favourable energy balance than when using sugar or cereal crops as feedstock together with energy intensive distillation techniques to produce the anhydrous ethanol. A full life cycle analysis is needed in order to accurately assess energy input/output ratios.

How are related issues best addressed by the consultation process?

Obtaining a resource/planning consent

The development of any heat, power or refining plant is usually subject to stringent planning measures not just for bioenergy. Strict regulations are in place in many countries to ensure air, water or land pollution do not occur. Each country has its own relevant legislation on emissions, landscape, planning approval, resource management, etc. Some state, regional or local authorities may impose even more stringent, over-riding conditions that will also need to be complied with. For large projects obtaining expert legal advice on these matters is often unavoidable. For small projects there may still be considerable costs involved for the developer, even with minimal professional input. Close liaison with the consenting authority well in advance should make the process more tenable in all situations.

Formal permission to construct a plant is usually required from local planning and other authorities who will consider the potential problems from discharging emissions to air, discharging effluent to waterways; the taking of water for cooling purposes; road access etc. The normally lengthy planning hearing process can be shortened if a proper submission has been prepared in consultation with all stakeholders. Inadequate consultation may result in legal action as the only recourse as might also be the case in circumstances under which consensus cannot be reached by the stakeholders. This costs time and money for all stakeholders so a due process of consultation is therefore recommended.

Consultation is part of the overall development process and should be integrated into it. Local communities are inevitably going to be affected one way or another by the construction and operation of a new bioenergy plant. The extent to which a community could be affected will depend on the scale and type of project. Even a small on-farm scheme can affect the neighbours so that consultation in advance, even if very informal, is recommended. This includes discussing issues relating to transport of the feedstock; the construction of the plant itself; times of construction working and plant operating; noise emanating from vehicles and plant operation; possible landscape change depending on the crops grown; light pollution if operated after dark; and the potential for increased workforce numbers to affect local house prices and demands on service facilities.

The project developer is responsible for managing the consultation process. If it is done well the project may proceed smoothly. In all cases it is recommended to undertake well planned consultation at an early stage of development in order to facilitate the planning and avoid the possibility of conflict resolutions occurring later which can be lengthy and costly to mitigate. The consultation process also needs to be flexible as a strategy may need to be changed as circumstances evolve.

Stakeholder analysis can often be a useful approach. Those people and organisations most likely to have an interest need to be identified from the onset. Gleaning information on local issues can also be beneficial in preparing for the critical consultation and communication strategy. If the industry is new in the region, then prepared, printed and presented educational material can be a useful tool to explain what the plant will look like and what all the possible impacts might be. This requires the developer to consider what possible impact the construction and operation of the proposed plant could have on the community and neighbourhood.

The developer will need to begin discussions with the local and regional statutory authorities at an early stage to help identify acceptable sites for the proposed bioenergy plant and to possibly eliminate those unacceptable for any reason. For example it may not be readily apparent from a map that a preferred site is actually a site of historic importance. Local authorities and government agencies are used to dealing with developers at an early stage of proceedings so early discussions, in confidence, can often prove helpful.

Those living and working in the vicinity of the proposed bioenergy plant including local interest groups and local authorities, together with other interested but non-resident stakeholders such as non-government organisations, will usually all have an interest in the project. Depending on its nature and scale, others with a possible interest could include:

- policy planners;
- local government agencies;
- transport authorities;
- tele-communication companies;
- civil aviation authorities;
- electricity regulators;
- historic places, archaeology and heritage organisations;
- water, waste treatment and waste disposal sectors;
- health and safety bodies;
- environmental and amenity groups;
- landowners and potential growers of the biomass;

- country user associations;
- wildlife, ecology and nature conservation groups;
- fire prevention bodies; and
- engineering consultants who provide technical services.

*Dev*elopers of a project are recommended to identify possible areas of concern for each relevant group and involve them at the appropriate stage. If the project is fairly novel in the region, this could be a time consuming process to explain exactly what is proposed. If it is one of a series of similar projects, consultation should become easier over time due to increased familiarity by members of the community as more similar projects are deployed, landfill gas projects being one such example.

Different groups will have different concerns. Those living and working near the proposed plant will require information on noise, visual impact, local emissions etc. Others may be more concerned about impacts on local landscape, recreational areas, water quality or even broader global issues such as climate change mitigation.

The timing of the consultation is often critical. If initiated too early it could raise concerns by the community that the developer has not even had a chance to consider. If left too late then the local community members could claim it is a fait accompli with no opportunity to receive their input. Where the project is the first in a district, the community will be unfamiliar with what is entailed and will generally imagine the outcomes to be worse than what they might prove to be in reality. Early consultation is then necessary on such detailed issues as transport routes, new power line routes, noise level contours etc.

Rapid responses by the project planner to any particular concerns identified by the public will help raise general confidence in this “new” industry, especially if it is the first plant of its type to be built in the region. Honesty and openness are respected. Where details requested have not been finalised at the stage reached in the development and planning process, then the community will probably understand the reasons and welcome the opportunity to comment on them as they are developed in the future. Where a firm decision has already been made on an issue and cannot now be altered to the extent that the community representatives might like it to be, then a clear explanation why it had to be made is often the best way to proceed.

Ideally the consultation process should be structured alongside the processes necessary for obtaining formal planning permission and resource consents. These vary from country to country. In some cases the process may need to be extended where aspects of the project fall outside of the usual formal legal process. In other cases agreement by government or the local authority may be all that is required with no community consultation needed at all. For example on-farm storage of manure feedstock in ponds to supply a proposed biogas plant may not need a formal consent in some countries but neighbours may need to be assured that odours will not become an issue. In other countries new plants might simply be built regardless of any local concerns expressed.

Methods of consultation will vary with the circumstances. They could include public meetings; open days; site visits to similar projects; special individual meetings with key groups; public exhibitions with good visuals of plans, plant diagrams, traffic routes; questionnaires; and discussion groups. It is usual for discussions to continue as the project proposal develops because new issues will inevitably arise at various stages. These may also concern the production of the biomass, especially if a new crop system will need to be developed involving land use change, water use issues, biodiversity monitoring etc. as could be the case with growing novel vegetative grasses or short rotation forests. Even after the project has been commissioned, liaison between the plant operators and community should continue to ensure no underlying problems have occurred and any required monitoring of emissions are fairly reported. This may be a condition of gaining the consent.

In some cases community members may be given the opportunity to become shareholders in the project. This “third party funding” approach may help ease the consultation process but will not eliminate the need for it. Generating pride in the project by the local community is a sign of success. This could entail encouraging new business developments such as guided tourist trails, nearby cafes, and school visits.

Regulations

Stringent controls already in place regarding planning zones, water access, road access for heavy vehicles, priority access to grid power line connections etc. may constrain a bioenergy project development. Often these are well established so are difficult to avoid, even by means of seeking specified departures from the local or government policies where a strong case can be made. Seeking amendments to existing regulations to better suit a new concept, possibly one not even thought of when the regulations were first drafted many years ago, is usually a slow and laborious process with much legal input needed. It may be possible to achieve success but often at a high cost and with major delays to the project.

National benefits versus local disadvantages

Virtually all energy plants have some form of impact on society. The dilemma can be where local “dis-benefits” are more than offset by any national benefits, and how these can best be judged. For example a series of bioenergy plants constructed in a region may cause increased local heavy traffic flows, noise and visual impacts for the residents. Conversely operation of the plants may mitigate thousands of tonnes of carbon dioxide each year which could have national and international benefits. There is no easy solution and each case usually tends to be assessed based on its individual merits by the consenting authority or through the courts.

What benefits and co-benefits should be included in an environmental impact assessment?

Climate change mitigation

Over the next decade as the carbon dioxide mitigation benefits of biomass become better understood by investors and carbon emissions trading expands, there is likely to be a significant increase in the total installed capacity of biomass-fuelled plants, including co-generation facilities for heating and cooling.

Carbon charges imposed on a society to offset the cost of greenhouse gas emissions from fossil fuels would increase the cost of fossil fuels and therefore make biomass more competitive. Bioenergy, being close to carbon neutral in most instances, should be made exempt (as should other renewable energy systems as well as nuclear power generation). The carbon revenue collected by governments from fossil fuel sales would have the potential to be used to create greater awareness of sustainable energy systems (including energy efficiency opportunities), particularly if the income could be recycled to encourage the use of biomass and other renewable energy projects or even support the cost of project development.

Carbon emission trading is certainly an incentive for renewable energy projects to displace fossil fuel use. Although carbon trading has begun in Europe and elsewhere, it is not yet certain whether it will proceed internationally over the long term and national greenhouse gas emission reduction obligations under the second commitment period of the Kyoto Protocol after 2012 have not yet been agreed. If trading does continue and expand internationally, then many bioenergy projects could receive additional revenue in terms of measurable carbon offsets. Others will possibly be built under the Joint Implementation and Clean Development Mechanisms of the Protocol and this could aid the rate of project deployment.

Security of supply

This is a complex subject revolving around future oil supplies, technical power system outages, sabotage and terrorism, geopolitics, weather patterns etc. Bioenergy (and other renewable energy) projects can assist in reducing the risks of these various energy supply constraints which can have serious political consequences. However they also carry their own risks of insecurity, variability and unreliability. A more detailed discussion can be found in the 2007 IEA publication *Contribution of Renewable Energy Technologies to Energy Security*.

The transport fuel sector in most countries largely depends on imported oil and refined petroleum fuels. Growing concerns regarding geo-political oil concentrations, limited reserves, and high and fluctuating prices have created considerable interest in alternatives including biofuels. Several types of biofuels exist but most remain more costly to produce (Figure 17), hence societal costs such as agricultural subsidies, grant support schemes, excise tax exemptions are all needed to further expand this fledgling industry. Even with climate change mitigation benefits and R & D investment to drive the production costs down over the next few decades, biofuels are unlikely to gain a major share of the market. However when produced for internal use by a country they are able to provide some transport fuel supply security, at least for maintaining emergency services.

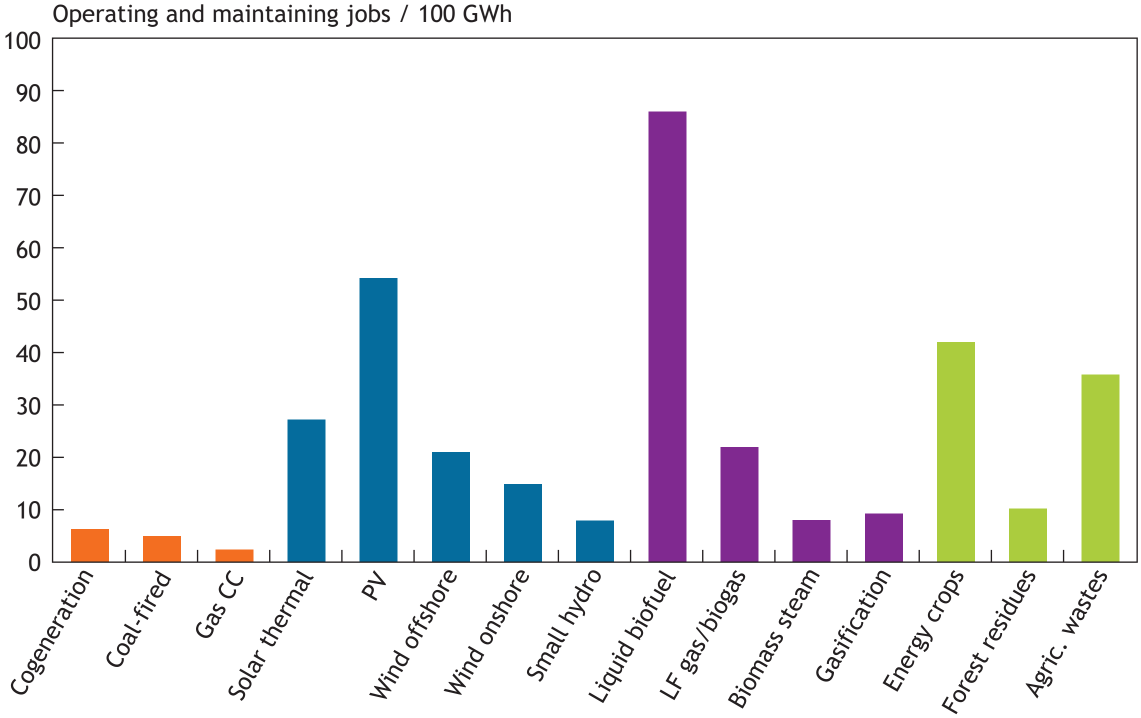
To enhance the security of power generation systems, bioenergy power and cogeneration plants built reasonably close to the demand load will reduce transmission losses and can at times strengthen the local electricity distribution grid by providing additional and alternative resources. Security of supply can also be improved by greater diversification of the portfolio mix.

For heating plants, greater security from using biomass fuels depends on the current source of existing oil, gas or coal fuels and their reliability, versus the risks involved with securing sufficient supplies of biomass over the long term.

Employment

There is little doubt that biomass can provide useful employment both for agricultural workers, possibly in the off-season when some harvesting or processing of energy crops can be carried out, and also for both skilled and unskilled workers at the bioenergy processing plant. Since bioenergy implementation depends on securing a reliable supply of sustainably produced biomass, it can create much needed employment opportunities in rural areas (Figure 19). Designing and building of the plants also creates jobs. However it should be noted that employing labour costs money. Hence if it is a relatively labour intensive process, producing bioenergy can become a relatively expensive option for providing electricity, heat or liquid biofuels energy carriers.

Figure 19 • *Employment requirements for energy projects*



Labour is required for operating and maintaining various renewable energy projects after their construction, with bioenergy projects also requiring additional labour to produce and deliver the biomass to the plant.

In some countries there may well be a future shortage of unskilled workers needed for the harvesting and collection of 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.

Health and emissions

It is possible to reduce emissions of both toxic substances and greenhouse gases by displacing fossil fuels with biomass. For example small (P_{10}) particulates from the combustion of mineral diesel fuel in vehicles travelling through cities are known to cause considerable increases in respiratory diseases and deaths. Biodiesel is thought to reduce such emissions, (although the relative volumes of other gases emitted may be higher). Conversely, poorly designed, often older, bioenergy plants using poor quality fuels can produce relatively high levels of particulate emissions. These however can be controlled, for modest additional investment costs, by proper installation of clean burning combustors and add-on facilities that meet modern air emission standards.

Some energy crops, particularly where perennial plants are grown, require relatively low inputs. For example the amount of agri-chemicals used per hectare can be reduced compared to many traditional arable crops under modern intensive crop management techniques. Health benefits can again result.

Although not covered directly in this report, it should be noted that traditional biomass use for cooking and heating by billions of people in developing countries causes health problems from smoke inhalation and carbon monoxide. Modern domestic bioenergy appliances, better wood-stove designs, and new biomass based fuels such as ethanol gels, can help reduce this major health issue.

Industry development

Biomass can be used at the small local scale for supplying heat for individual buildings such as schools or hospitals. It can be used for drying crops or for heating houses, animal buildings or greenhouses on a farm or in a village. These applications can often save on energy bills. Larger scale schemes can provide process heat, district heat, electricity for use on-site or fed into the national grid, or biofuels for blending into the regional transport fuel supply at the refinery. The size of a bioenergy plant usually does carry economies of scale but these are often constrained by the additional transport costs if having to collect the biomass from larger distances (Table 1).

Regardless of the scale of plant the manufacturing industry will need to be expanded in order to design and build more appliances as increased deployment occurs. In addition more ancillary handling and processing equipment will be needed. Together this will provide local employment and possibly export opportunities for some manufacturing companies.

Waste treatment and disposal

In extreme cases growing energy crops may also provide the potential for cleaning up radioactive contamination of land (as is being undertaken near Chernobyl), absorbing heavy metals from mining tailings, and enabling the phyto-remediation of chemically contaminated soils. Care is needed when using such biomass sources in a bioenergy plant however as any heavy metals or radioactive concentrations would need to be contained during the energy conversion process with the ash possibly needing to be disposed of as a hazardous waste.

Beneficial environmental impacts from the use of biomass (see Section 2) include improving sewage treatment prior to discharging effluent and sludges to waterways or oceans; avoiding methane emissions from landfills; and reducing odours from direct application of animal wastes to land by first processing in a biogas plant.

Landscape and biodiversity

It can be argued that if energy crops and integration of biomass products are included in the general mix of agricultural crops in a considered and informed way, that there could be significant environmental and ecological benefits to be gained alongside the production of a fully sustainable energy resource. Some energy crops such as short rotation coppice forests can provide landscape variety and a habitat suitable for attracting other species of plants, birds and wildlife. If neighbouring blocks of land are planted sequentially over several years and harvested on a rotational basis, then some of the area will always contain mature stands. However care will be needed to ensure harvesting does not occur at critical breeding or flowering periods for the fauna and flora that are being encouraged.

Encouraging bird life and biodiversity by planting energy forests can, if carefully planned, also enhance the landscape. Planting on the contour rather than in straight rows is one simple approach, though subsequent harvesting my machinery may be more difficult. Some recreational activities such as walking, hunting, cycling or bird-watching can be encouraged on land growing some types of energy crops.

How can strategic support policies for bioenergy be integrated with other local and national policies?

Linking national bioenergy objectives and targets with other government policies to achieve similar goals is a strategic way forward. Such policies can include:

- **greenhouse gas mitigation** by displacing fossil fuels and providing both physical and chemical carbon dioxide capture and storage opportunities;
- **security of energy supply** by expanding the energy portfolio and encouraging the uptake of local renewable energy systems and alternative fuels;
- **increasing employment** opportunities by using skilled and unskilled labour in larger bioenergy projects, in the plant and equipment manufacturing industry, and in rural areas;
- **transport** by encouraging the uptake of biofuels;
- **water quality** by encouraging riparian strips and effluent treatment on to land;
- **waste treatment and minimisation** by landfill plants and various other waste-to-energy projects;
- **rural development** in developing countries, in particular to provide the necessary energy supply using indigenous resources;
- **land use diversification** including the stated aim in some regions to de-couple agricultural subsidies from food, stockfeed and fibre production in the longer term; and
- **social issues** such as the long-term goals to establish sustainable cities.

The first five of these policies have already been discussed in the section above. More general comments followed by additional points on the other four policies follow below.

Policies to support bioenergy will be needed if its share within the global energy mix is to be increased. Policies can be established to directly encourage the production of biomass by, for example, encouraging land use change or placing high prices on organic waste disposal at landfills. Alternatively policies can be applied indirectly by encouraging the demand for bioenergy (with separate policies needed for heat, power and biofuels) which would imply the need to secure more biomass as feedstock for the conversion plants.

Bioenergy project deployment will partly depend on future world oil, gas, coal and carbon prices making biomass more or less competitive with fossil fuels. However at this time where the rate of deployment of bioenergy projects is in the balance, more often than not regulatory and fiscal barriers exist. These include an absence of effective markets, such as green pricing, to stimulate the bioenergy industry in many countries and the continuation of grants and subsidies that support fossil fuel energy systems. Together these make the entry of bioenergy into the market more difficult.

Overall bioenergy has been envisaged to become a more significant contributor to global renewable energy in the short to medium term. Estimates of its future market potential and costs vary widely due to the complex characteristics of the resource, their site specificity, uncertainties around supporting national policies, labour input costs, and efficiency of the conversion technologies used. However, overall the costs are expected to continue to decline over time, whilst the social and environmental co-benefits, including carbon sequestration opportunities, are anticipated to become drivers of greater bioenergy project deployment.

Waste treatment

Increases in the cost of disposal of wastes and residues, driven by growing environmental concerns, will necessitate the need to find alternative options. Waste-to-energy projects not only avoid the cost of disposal but provide useful and valuable outputs in the form of methane, heat and electricity energy carriers.

Rural development

From the social perspective there can be little doubt that bioenergy projects protect existing rural employment, provide new jobs, give learning opportunities in order to transfer skills, introduce new skills, and provide training and educational opportunities. The growing interest towards distributed heat and electricity generation using smaller scale plants and embedded power generation systems 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. Once proven in developed countries the concept can then be easily transferred into developing countries together with capacity building initiatives. This in turn will produce a sense of pride and independence, of particular importance to many indigenous and aboriginal communities who are struggling to maintain their cultural identities.

Land use diversification, subsidies and trade

Energy crops and the use of arable and forest residues for biomass can contribute to farm product diversification and, depending on national policies, either attract more grants and subsidies or, with careful long term planning, reduce the dependence that many farmers now have placed on "farming for subsidies". The ability for removal of agricultural subsidies over time could become another major driver for encouraging energy crops, especially in Europe and the USA. Some of these aspects can vary from region to region, and are very different between developing and industrialised countries. In developing countries there can also be synergies between the greater uptake of modern biomass and sustainable development, at least until increased competition for industrial raw materials or fertile land results.

In Europe, due to the carbon emissions trading system and other biomass related policies, raw materials normally for industrial use are already being directed to energy uses in Scandinavia and other European countries. There are also possible conflicts over land use arising with food production and biodiversity. On the other hand, energy crop production could provide the potential for engaging the agricultural communities of many industrialised countries by shifting support from food, feed and fibre production, especially where there is a prospect of producing surpluses of these commodities.

In EU 25 Europe, several of the ten new member states have large arable land areas not previously well managed. So the opportunity to grow energy crops rather than to seek subsidies to produce increased volumes of food and fibre is worthy of evaluation. Based on the experience of the Common Agricultural Policy (CAP) by the EU 15, targeted revenue policies could be a more suitable option than support price policies. These worked well initially under the European CAP when the original objective was to obtain more food during the post-war scarcity in the 1950s/60s. But then it could be argues that the policy largely failed once surplus food became available. Currently under the common perception of an energy supply scarcity, a similar approach could be taken for energy crop support, but with the aim of phasing out any price subsidy over time as greater experience is gained and the production costs fall.

The whole biomass trade issue is complex and is under evaluation by the OECD, Global BioEnergy Partnership (www.globalbioenergy.org) , IEA Bioenergy's Task 40 (IEA BioenergyTrade, 2007), and elsewhere. Several IEA countries are already purchasing some of their biofuel from other producers such as Brazil and Malaysia. Others are seriously contemplating doing so to meet growing demands. Importing biomass could prove to be a cheaper option than producing their own, partly depending on any trade tariffs imposed. However since there are very limited volumes of solid biomass and liquid biofuels available for sale on the world market at present, and the energy and economic costs of transporting the biomass would need to be included in any comparison with local production, given the anticipated increases in demand, the future price of biofuels is likely to increase significantly.

In addition, it would seem sensible for a developing country producing bioenergy carriers to use them internally to aid its future economic development, rather than to gain short term income from exporting them. A joint workshop between IEA Bioenergy Task 40 and the World Bank however concluded that a combination of producing bioenergy carriers for export as well as for local use would generate revenue for development from the export earnings as well as support local industry (IEA BioenergyTrade, 2007). Sustainable production of biomass and its utilisation in order to preserve the local food situation and protect biodiversity is a prerequisite in developing this new potential. So overall, the extent to which the international trade in biomass will develop is uncertain.

Social policies

Other than employment, health and rural development, many countries have national polices relating to social cohesion, education, pride, support for indigenous peoples etc. The IEA Bioenergy (2007) has an activity (Task 29) covering the *Socio-economic aspects of bioenergy systems* within its Implementing Agreement and more details can be found at www.eihp.hr/task29.htm.

Education and easy access to information about the problems of energy supply security, climate change and greenhouse gas emissions may create greater awareness and encourage companies, communities and individuals to be prepared to act. This could involve behavioural change in the longer term and result in the immediate uptake of more biomass and other renewable energy systems.

There is a growing trend towards communities taking responsibility for their local environment. Bioenergy provides the opportunity for many people living in cities to also have an improved quality of life. Private ownership of bioenergy plants such as biogas plants in Denmark or district heat and power cogeneration plants in Sweden are good examples.

In poorer urban areas in developing countries, bioenergy plants could provide social benefits resulting from having lights to read by and for children to complete their homework. In wealthier countries biomass benefits could be in terms of better levels of home heating or cooling. For individuals, communities and businesses based in cities who value the goal of achieving sustainability for whatever motive, using biomass as an energy source could help meet their objectives of becoming self-sufficient, renewable energy supporters, low carbon emitters, and also becoming recognised as environmentally aware and responsible citizens.

Bioenergy support policies

Government support schemes for renewable energy can be applied to bioenergy in most instances. Direct government grants and subsidies for biomass production could encourage further uptake of bioenergy projects, but these would need careful consideration as to their permanence; the industry possibly building a long-term reliance on them; and how their future phasing out and removal would affect the industry. Ideally policies need to be made for the longer term, particularly for the bioenergy industry since energy crops can take time to grow and projects can take time to develop.

For electricity there are two main types of mechanisms.

- RECs and ROCs (renewable energy certificates / renewable energy obligations) As well as selling the electricity privately or through the wholesale market, electricity generators and retailers are able to trade renewable energy certificates issued after generation from specified types and scales of generation plant. Trading via an internet-based market has begun in several countries. The rights are sold into the market once the power is generated and the price varies with varying supply and demand. The certificate value can be capped by imposing a penalty that retailers will have to pay if they do not meet their renewable electricity targets as set by the regulations. Renewable electricity markets have good potential to boost bioenergy projects with landfill gas plants gaining most interest to date.

  Targets set by governments for new renewables including bioenergy can be successful in gaining increased uptake. Australia for example, with its 2% (9,500GWh/y) mandatory renewable energy obligation on electricity retailers by 2010, has made good progress because most power generation companies soon identified commercial projects in which to invest. Bioenergy will be a major provider of this target since landfill gas, bagasse and forest residue-fuelled bioenergy power plants are being built that can be cost-competitive with wind and solar under Australian climatic conditions. Combined heat and power plants, and the co-firing of biomass with coal or gas, are more difficult to monitor so are not always included in a RECs portfolio of approved projects.

- Feed-in tariffs An alternative popular government incentive would be for bioenergy generation plant operators to receive a fixed price for any power generated that is normally above the market price. Advantages are that new project investors are able to estimate their total revenue in advance since this additional income can be included as a fixed price into the project economic analysis.

For biofuels, mandatory obligations on oil companies to provide a certain percentage of biofuels in their products is becoming a popular approach to stimulate increased market shares. Policies to support renewable energy heating and cooling that relate to bioenergy are scarce.

Bioenergy project developers should follow closely any national policy developments as they occur. They are continually being produced and updated. A full list of policies and measures that relate to government policies to support bioenergy can be found on the IEA database at http://renewables.iea.org

Summary

Biomass currently provides a significant amount of global consumer energy but mainly for traditional domestic cooking and heating in developing countries. New and improved modern bioenergy technologies for electricity, transport and industrial heat production have reached the market and, in some cases, are successfully competing with fossil fuels even without government incentives, especially in the landfill gas and heat markets. Modern bioenergy projects however are not developing as rapidly worldwide as had been anticipated.

Many potential investors and developers do not have a good understanding of the technical, social and environmental issues that should be addressed when seeking approval to develop a bioenergy project. Ready access to information on biomass fuel supply and quality issues, bioenergy plant design and technologies, conversion plant economics etc, could assist their understanding. This should help meet the industry objective to install good quality, well designed bioenergy plants in order to gain a good return on investment from meeting growing energy demands using sustainably produced biomass fuels.

However the process for developing a bioenergy project can still be complex in comparison with building a wind farm or small hydropower scheme. It is anticipated that a more thorough understanding of the issues involved in developing a bioenergy project, as outlined in these guidelines, should enable the project approval process to stand a greater chance of success. As global energy demand is projected to continue to grow, all options must be pursued.

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IEA Publications
9, rue de la Fédération
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Printed in France by the IEA
June 2007