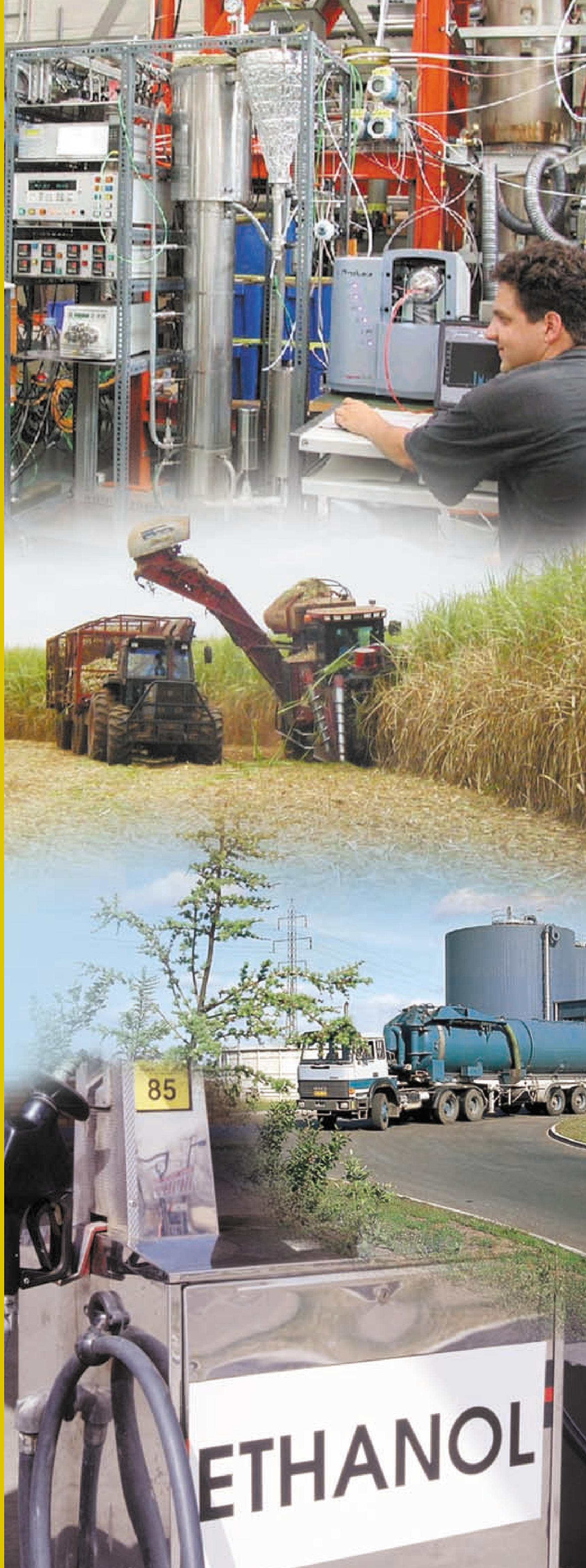
Benefits of Bioenergy

This publication presents bioenergy in the context of energy choices, and identifies linkages to wider sustainable development outcomes. It outlines the wide range of biomass sources and conversion technologies available, and discusses social, environmental and economic aspects of bioenergy systems. Case studies are provided to demonstrate practical bioenergy solutions that both satisfy energy demands and address wider issues.



IEA Bioenergy

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Introduction

Bioenergy is the most widely used renewable source of energy in the world. It provided almost all global energy two centuries ago, and still it provides 11% of the world primary energy supplies. A wide range of environmentally sound and cost-competitive bioenergy systems are already available to provide a substantial contribution to future energy needs. The International Energy Agency Bioenergy Agreement is supporting the realisation of the sustainable potential of this significant renewable energy source.

Modern industrialised societies function within an internationalised economy which comprises many political, environmental and economic agreements, and an array of national instruments designed to address sustainability issues. There are global trends towards more sustainable production methods, waste minimisation, reducing pollution, conservation of natural resources, and reduction of greenhouse gas emissions. Bioenergy activities are influenced by these factors which play a large role in the future of bioenergy in society.

Energy is a key issue for most countries, largely in terms of security of supply and costs. The relationship between fossil fuel consumption and increasing atmospheric concentrations of greenhouse gases is causing concern, resulting in actions to mitigate against or adapt to an uncertain future climate. These and many other global issues can be considered as components of sustainable development that will provide for our needs today without compromising the ability of our children and future generations to meet their needs. Each generation can benefit from the interest from natural capital, but must maintain the principal intact to ensure future prosperity.

The awareness of environmental issues will increase as evidence grows of the gradual degradation of the quantity and quality of non-renewable resources. The role of natural ecosystems in social and economic activities will become more apparent, and the need to reduce or remove the negative impacts of economic activity on the ecosystems will become more urgent. The concept of sustainability acknowledges that the economy exists in the context of society; consequently economic activities function only within society and are constrained by the natural systems of the planet. Biomass production, use and disposal in food, fibre and fuel are thus integral to the functioning of society.

Energy Choices

Global energy demands are rising and must be addressed because current production systems and consumption patterns are unsustainable. Energy efficiency and conservation can reduce consumption of resources, but other sources of energy will be required.

The global energy market is dominated by fossil fuels (Figures 1 and 2). Renewable energy plays a larger role than nuclear power in both total primary energy and electricity statistics. While renewable energy is gaining support, the nuclear industry continues to face issues such as perceived concerns over safety and radioactive waste disposal. Fossil fuels are finite resources, and there are concerns about the security of supply and cost of these reserves, particularly oil. Fossil fuels are hydrocarbons formed during the fossilisation of carbohydrates in biomass. It is this similarity which makes biomass fuels complementary with, and suitable as a substitute for, fossil fuels. It is the compatibility of bioenergy with existing energy systems that will facilitate increased adoption of biomass fuels for heat, electricity and transport.

Ethanol pilot plant based on corn fibre and other cellulosic material, New Energy Company of Indiana, USA. (Courtesy DOE/NREL and W. Gretz)

A renewable energy is one that produces electrical, thermal or mechanical energy from natural energy flows, without depleting the resource that feeds it. Bioenergy is one of the family of renewable energy sources that also includes wind, solar, wave and hydro-power. Renewable energy sources tend to be complementary to each other, and as the sun, wind and rain come and go, biomass acts as the rechargeable battery that is available on demand.

At a world level biomass is the largest renewable energy source in use today (Figure 1) and represents over 1.11 billion tonnes of oil

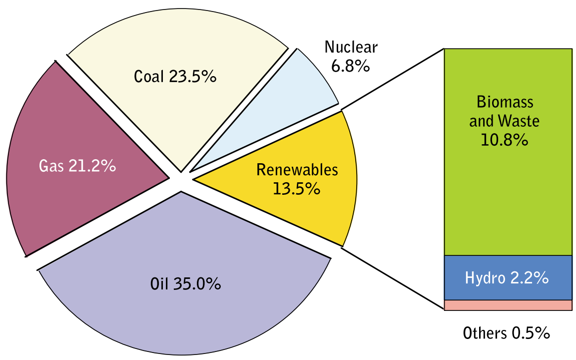


Figure 1: Share of biomass in world total primary energy supply - 10,321 Mtoe in 2002. (Source: IEA Renewables Information 2004)

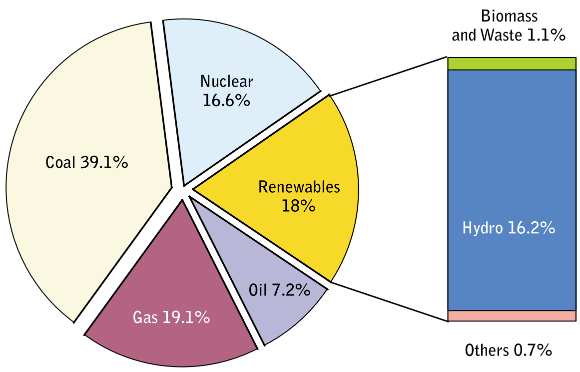


Figure 2: Share of world electricity production from biomass - 3,764 Mtoe in 2002. (Source: IEA Renewables Information 2004)

equivalent. Bioenergy is derived by harnessing the energy flows collected by nature's solar collectors: plants. It is this natural storage capacity that differentiates it from many other types of renewable energy. It offers options for providing energy when other renewable energy sources are unavailable.

The biomass must be produced sustainably or this natural resource will be depleted just like fossil fuels. There are also other important considerations in selecting an appropriate energy system. A comparison of the social, economic and environmental aspects of utilisation of different energy sources indicates many positive aspects of renewable energy sources. Some of these aspects are discussed below and demonstrated in the case studies.

The Timberjack Slash Bundler harvesting forest residues. (Courtesy Dr A. Timperi, Timberjack, Finland)

Biomass and Biofuels

Biomass is largely composed of carbohydrates and lignin, produced from CO_2 and water by photosynthesis, thereby capturing solar energy in living plants. This energy in biomass can be harvested and stored for subsequent release.

Biomass production systems are frequently focussed on the production of food, animal feed or fibre, although in some cases there is an energy by-product. All biomass residues can produce bioenergy, and organic wastes can still produce energy after they have served another purpose.

Biofuel is a term used to describe biomass processed into a more convenient form for use as a fuel. It commonly applies to liquid transport fuels, but could also include gas and solid fuels such as wood pellets. While many types of biomass can be converted directly into heat or power, some types of biomass are more suited to conversion or refinement into an intermediate biofuel. These fuels may have a range of desirable properties such as better storage, ease of handling, greater convenience, compatibility with existing fuels, or higher energy density.

Biomass is already obtained from the agriculture and forestry sectors, as a residual product from harvesting or as purpose-grown crops of trees and other plants. Wastes are also commonly used, either directly in heat and power plants or to produce biofuels such as biogas from landfills and sewage treatment plants.

Forest and farm residues

Forestry and agriculture activities typically leave large amounts of biomass on site after harvesting e.g. branches, tree tops, straw, corn stover, and bagasse from sugar cane. Instead of looking at this as waste, it should be considered as a feedstock for bioenergy. In some cases there is a need to leave a proportion of the waste to protect or enhance the site quality, or to create habitats. In other cases the removal of wastes can facilitate ground preparation or replanting operations, or reduce risks of pest and disease outbreaks. These crop residues tend to be dispersed in the environment and may suit smaller scale bioenergy applications in order to minimise transport distances.

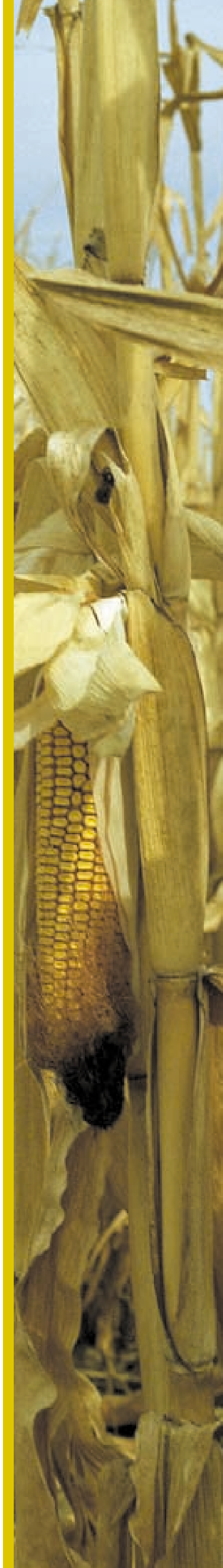
Farm animals also produce wastes that offer energy potential. Animal dung is used as a fuel in some parts of the world, and effluents are commonly digested to produce biogas.

Case Study **Sweden: fossil fuel substitution initiatives**

Växjö, a city of 77,000 people in southern Sweden, is working to become fossil fuel free. Växjö is taking the initiative to influence public opinion and government, to develop new strategies and methods for environmental improvement in general, and to reduce greenhouse gases in particular. In 1996, the city of Växjö decided that they would reduce emissions of CO_2 from fossil fuels by 50% per capita by 2010 compared with 1993. By 2003 they were down to a per capita emission of fossil CO_2 of 3,680 kilograms per year compared with the average for Sweden of around 6,000 and Europe around 9,000. This example of acting locally while thinking globally is being implemented through increased use of biomass for energy and by using biofuels for transport and district heating.

Delivery of pellets to a villa outside the district heating zone in Växjö, Sweden. (Courtesy P. Westergård, Sweden)

The Växjö Energi AB 104 MW Biomass CHP plant. (Courtesy P. Westergård, Sweden)



Energy crops
Energy crops include a range of annual and perennial, and herbaceous and woody species. Short-rotation woody crops use fast-growing species (*Salix, Populus, Alnus, Eucalyptus, Miscanthus*) grown on rotations of 1-15 years to produce 10-15 dry tonnes/ha/yr. Sugar, grain, and oil crops are also grown, focussed more on the production of transport biofuels such as bioethanol and biodiesel.

These crops may be best suited to high value energy products and services to offset costs of a dedicated biomass production and supply system. They may also prove to be valuable as a supplementary fuel used if other biomass wastes cannot satisfy demands.

Four-year-old willow (Salix) - a renewable fuel supply.

Processing waste
Woody biomass often comes as a by-product of forest processing plants such as sawmills, furniture plants, and pulp and paper mills. Bioenergy offers an environmentally sound alternative to disposal of these 'clean' residues, usually to produce heat and/or power. Frequently, energy generation is greater than needed on site and surplus electricity can be sold to the grid. However, wastes may represent resources other than energy. There are many new

Transporting sawdust and bark to a biomass heating plant. (Courtesy Stadtwärme Lienz, Austria)

processes and products that can utilise the smaller logs, particles, and fibres that were once discarded. Competition for these resources is likely to make them more expensive.

Wastes from agricultural processing can also be used to produce bioenergy. Typically these are converted into biofuels, either biogas from waste/effluent digestion, or liquid fuels by fermentation.

Municipal wastes
Modern industrialsed societies are 80% or more urbanised and produce huge amounts of municipal solid waste (MSW) from domestic, commercial and industrial activities. Garbage and sewage are frequently disposed of in landfills or treated using expensive processes.

MSW can be seen as a liability or as an opportunity for recycling and reuse. Typically up to 80% of the carbon content of MSW is biomass-derived (Figure 3). MSW has a calorific value of 8-12 gigajoules per tonne (GJ/t) compared with 25 GJ/t for coal. One tonne of MSW can produce about 600 kWh of electricity with net emissions of about 370g CO_2 per kWh. Comparable emissions values for gas and coal are typically 450g and 1,000g CO_2 per kWh.

Generating energy from MSW avoids potential issues over leachates and groundwater contamination from waste disposal sites. There have been concerns over the combustion of non-biomass materials and finishes (paint, preservatives, ink etc) but local environmental effects can be minimised using best practices. Technical problems due to the variable composition of MSW can be addressed at the

Case Study **Japan: combined heat and power from forestry**

Kahoku Town is located in Kochi Prefecture at the southern part of Shikoku Island. Its highly forested area (84%) produces abundant wood resources that are highly utilised in Kochi Prefecture. Many sawmills produce large quantities of wood waste. The combinations of production facilities and markets make it easy to gather biomass fuels from nearby towns for processing. Both sawmill waste and forestry waste are used as a feedstock to produce heat and power in gas turbines. All the heat produced is utilised in public facilities although total heat production largely exceeds the demands. The co-generation system cannot supply all the electricity used in the public facilities, and because of the price structure in the area, it is most profitably sold to the grid.

Case Study **Canada: community heat from sawmill residues**

A wood-fired heating plant in the village of the Oujé-Bougoumou Cree Nation (northern Canada), has supplied heat and hot water since 1992. The system uses local sawmill residues as a fuel and provides local employment and reduces CO_2 emissions from fossil fuels. It gives residents a measure of control over their society and serves as a model for community sustainability.

input and output ends. In some cases MSW is converted into a refuse-derived fuel (RDF) to improve its characteristics. It is also essential that MSW recovery systems integrate with other methods of treatment, recovery and disposal.

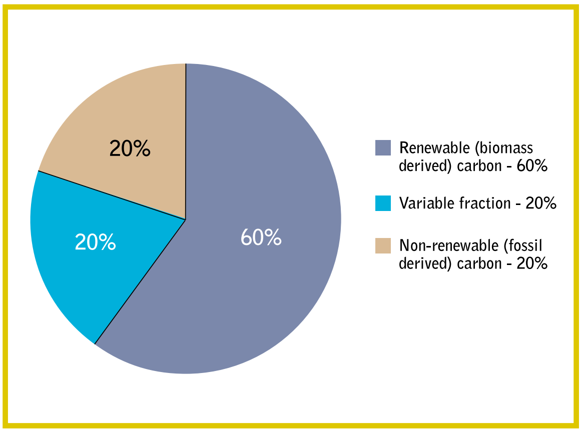


Figure 3: Carbon content of MSW (% by weight).

Conversion Processes

Several conversion routes are used to change raw biomass into useful forms of energy and to provide energy services such as heat, power, or transportation. Some forms of raw biomass can be converted to an intermediate biofuel before providing a service (Figure 4, Table 1). Biomass and biofuels can be converted to energy via a range of technologies including engines, boilers, refineries, turbines, fuel cells, and others.

Conversion routes for biomass are generally thermochemical or biochemical, but can also include chemical and physical. Biodiesel is engine fuel produced from rapeseed or other vegetable oils through the process of methanol and other alcohol esterification and has similar properties to the standard diesel produced from fossil fuel. Physical methods are frequently employed for size reduction of solid biomass e.g. chipping, but may also be used to aggregate and densify small particles into pellets or briquettes.

Combustion is the most widely used technology that releases heat and can also generate power by using boilers and steam turbines. It is one of the simplest technologies and typically has electrical efficiency of only 20-30%. In combined heat and power systems it can have very high (80%) overall energy efficiency.

Gasification processes also produce heat and power but may be more demanding in terms of feedstock specifications e.g. moisture content and particle size. They enjoy higher electrical efficiency and can be more suited to large (>10MW) installations where electrical energy is in demand and commands premium prices.

Pyrolysis describes the process of anaerobic decomposition of biomass at elevated temperatures to produce solid, liquid or gaseous products. The type and ratio of products (particularly oil:char) depend on the speed and temperature of the process. Fast pyrolysis can yield up to 80% bio-oil whereas slow pyrolysis produces more char. Pyrolysis products tend to be biofuels that can be stored or transported for use in subsequent and separate energy production activities. Other compounds/chemicals may also be extracted from pyrolysis oil which can improve process economics.

There are several biochemical processes used to produce gas and liquid fuels. Sewage and effluents can be anaerobically digested to produce biogas, usually a mixture of methane and carbon dioxide. The undigested sludge residue can be dewatered and burnt or used as a soil improver. Many landfills also produce biogas, and current designs facilitate the collection and use of the gas emitted.

The sugars in biomass can be fermented to produce bioethanol. This usually follows some form of hydrolysis pretreatment of the raw biomass. Global production of bioethanol is primarily derived from grain and sugar crops, but the utilisation of lignocellulosic (woody) biomass is a current research and development focus.

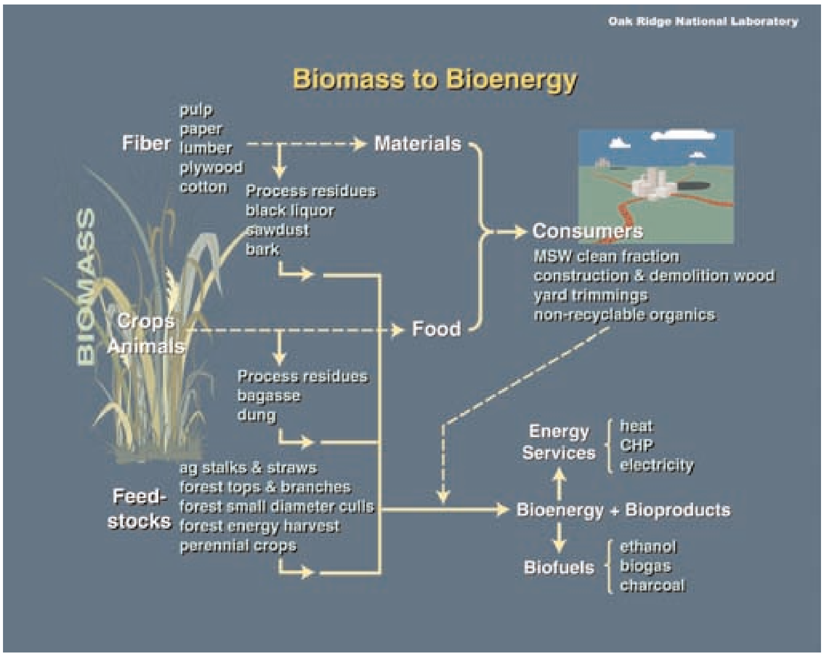
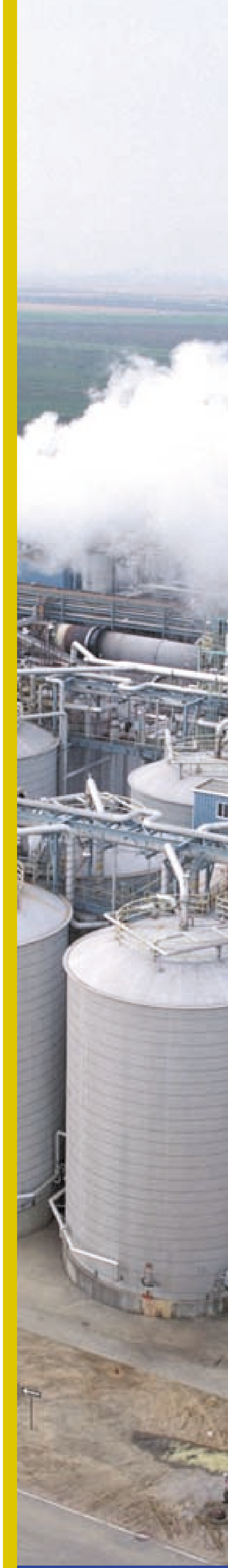


Figure 4: Sources and routes for converting biomass into useful energy.

Case Study — Croatia: solid biofuels from wood-waste

A wood processing company near the town of Varadin in northern Croatia produces furniture and approximately 35,000 m^3 of wood waste annually. At one time the wood waste was used as fuel for the local heating plant and smaller quantities were sold to households. A factory was built in 1999 to utilise excess wastes and to supply an increase in demand for briquettes and pellets. The plant has a total production capacity of 3,600 kg/h, and is operated by seven workers. The heating plant produces around 66 TJ annually which replaces approximately 1.5 million litres of heating oil. This represents a saving of about 819,000 Euros and lowers greenhouse gas emissions by 15 kt CO_2. The total energy potential of different biomass types in Croatia amounts to approximately 50 PJ. Research conducted at the national level shows that energy production from this biomass could offer approximately 4500 new jobs by 2015.



Process Development Unit for biomass to ethanol, 9000 litre fermenters, Golden, Colorado, USA. (Courtesy DOE/NREL and W. Gretz)

Bioenergy Products and Services

Bioenergy products range from a simple log, to a highly refined transport fuel. Different products suit different situations and objectives. The choice of product may be affected by the quantity and cost of biomass types available, location of fuels and users, type and value of energy services required, or other co-products. It may also look at the carbon and energy balance of the process, the political support, the financial performance or the social impact. In each case a different combination of factors may be considered highest priority.

Biomass can provide thermal, electrical and mechanical energy services. Heat/steam is often given lowest value relative to electricity and transportation. Highest overall efficiency is often a result of capturing more than one service e.g. in combined heat and power plants.

Table 1. Routes for converting biomass into energy products and services

Biomass Resources	Processes	Biofuels	Energy services
Agriculture and forestry residues	Densification Esterification	Wood pellets Briquettes Biodiesel	Heat Electricity Transport
Energy crops: biomass, sugar, oil	Combustion Gasification Pyrolysis Fermentation/Distillation	Char/charcoal Fuel gas Bio-oil Bioethanol	Heat Electricity Transport
Biomass processing wastes	Digestion Hydrolysis	Biogas Bioethanol Solvents	Transport
Municipal waste	Digestion Combustion Gasification	Refuse-derived fuel (RDF) Biogas	Heat Electricity

Case Study — United Kingdom: power from poultry litter

The Fibrowatt Thetford poultry-litter power station is one of the largest plants producing power from biomass in Europe. The plant consumes approximately 400,000 tonnes per year of poultry litter complemented by other organic fuels. Poultry litter is collected in covered lorries from nearby farms and delivered to a 4,000 m^2 specially designed fuel hall with a capacity of 10,000 tonnes. This is equivalent to one week's supply, so avoiding weekend deliveries.

The plant has an output of 38.5 MW of electricity, sufficient to supply a town of around 93,000 homes. The electricity produced is fed into the local grid, and steam is condensed to water by air-cooled condensers and subsequently recirculated into the boiler. The power station is open to visits by local residents and educational groups. This plant, one of three similar ones in the UK, uses a substantial proportion of the more than 1.5 million tonnes of poultry litter produced annually in the UK. The by-products and wastes from the plant are mainly gases and ash. The exhaust gas is treated in order to fulfil the legal requirements at UK and European level and the ash is sold as an 'environmentally friendly fertiliser' (Fibrophos), as it is rich in phosphates and potash and is nitrate-free. The plant has also had a positive impact in terms of job creation - about 300 people were employed during the building phase and around 30 permanent staff operate the plant.

Case Study — Ireland: biodiesel and animal feed from oil seed crops

A facility for production of pure plant oil [PPO] from oil seeds was commissioned in 2003 in Adamstown, County Wexford. The County has about 59,000 ha of land used for producing arable crops, and 4,000 ha of 'set-aside' land. The facility is capable of an annual production of 480 tonnes of PPO (usable in diesel engines) from 1,400 tonnes of oil seeds. The by-product 'oilseed cake' is a high quality protein animal feed. Markets are being developed for both products, and this small plant can be expanded to commercial size if the process proves itself.

This operation provides farmers with an additional crop option, and also has support from public authorities and the financial community, all of which fosters other economic developments in this rural community. Locating the market close to the producer reduces transport costs for agricultural products going to market. Environmental issues of using PPO are minimal. There is no sulphur and reduced vehicle emissions, smoke, particulates, hydrocarbons, and greenhouse gases compared to using diesel fuel.

Environmental Aspects

There are multiple environmental benefits of using bioenergy including:

- reduced pressure on finite natural resources
- reduced landfill waste and associated issues
- protection of groundwater supplies and reduced dryland salinity and erosion
- maintenance of logging sites in a clean state for reforestation
- increased terrestrial carbon sinks and reservoirs
- the return of land back into production with enhanced biodiversity
- reduced GHG emissions via fossil fuel substitution

The extent to which one or more of these occur depends on the specific system design and location, and the boundaries used in the analysis.

Returning nutrients to the forest by spreading ash from wood fuel combustion. (Courtesy P. Hakkila, Finland)

Conservation of natural resources is a common objective. In bioenergy systems this can include reducing the use of non-renewable resources, maintaining the quality of resources, or recycling and reusing resources.

Waste to energy has the potential to make a significant contribution to sustainable development by helping meet the Kyoto obligations. Other positive attributes include an opportunity for materials recovery, positive benefits relative to fossil fuel-derived energy, reduced GHG and acid gas emissions, reduced depletion of fossil fuels and reduced impacts on water and land contamination. Deployment of MSW energy recovery should be encouraged wherever it presents a viable and attractive way of integrating with recycling and re-use activities and minimising the impact of waste disposal.

The current patterns of energy use, and associated links to emissions of greenhouse gases and climate change, are of major global concern. Fossil fuel substitution is a key role of renewable energy, leading to emissions being reduced, or further increases being avoided. Renewable energy systems should avoid fossil fuel intensive processes and materials to optimise carbon balance and energy ratio.

Bioenergy is unique amongst the renewable energy technologies since it plays a role in the maintenance and enhancement of terrestrial carbon stocks as well as reducing the emissions from fossil fuels. These impacts are not restricted to the forest, and they vary between production systems. Long rotation forests can accumulate large quantities of carbon but tend to do so fairly slowly. Shorter rotation plantation species have higher productivity and carbon sequestration rates, but are harvested more frequently and do not achieve such high carbon stocks. Longer rotations favour the production of longer lived wood products which can delay the release of the carbon back to the atmosphere. Discarded wood products and paper products can also be used for energy after they have served a useful life, or been discarded and perhaps locked up in a landfill. Shorter rotations imply more frequent operations which may mean more intensive energy use. Most pulp and paper products are more energy intensive than sawn timber and board products, but some processes can meet all their energy needs from biomass and hence report no GHG emissions.

Biomass is considered 'GHG-neutral' because it contains carbon that is circulating in the environment (Figure 5), as opposed to carbon in fossil fuels from geological formations. The latter is effectively a finite resource, and its use represents a one-way flow from beneath the earth's surface to the atmosphere. Biomass is commonly formed by the process of photosynthesis in plants which

Case Study — Sweden: reducing emissions with biomass-based district heating

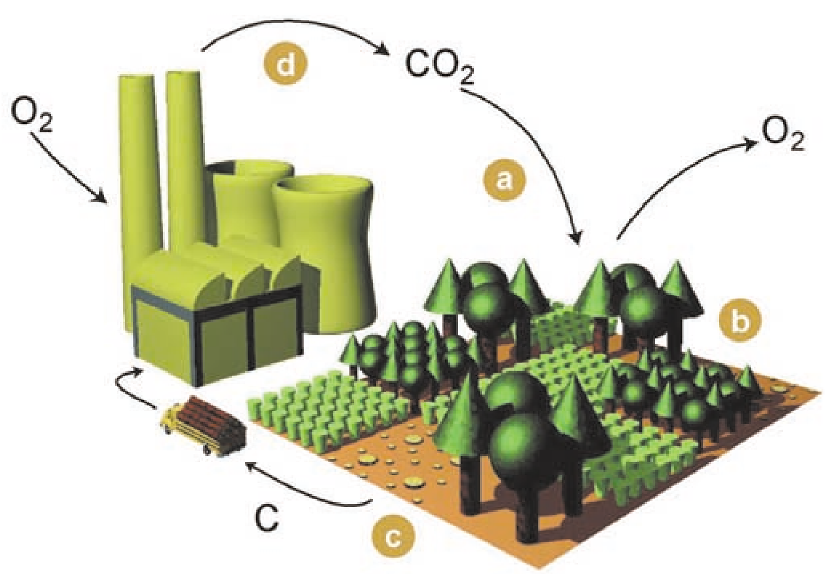
A low-emission biomass plant in Hoor, Sweden delivers about 15 GWh annually to the district heating network, which is about 85% of the heat used by the network. There are strict emission limits since the plant is located near a school in the city centre, and to reduce these emissions the flue gas is cleaned in a wet electrostatic precipitator before it enters the condenser.
An additional feature of the recycling system is the reduction in emission of nitrogen oxides. The payback time for the plant is estimated to be approximately four years.

Case Study — Norway: district heating at Oslo airport

The heating system for Oslo's new international airport at Gardermoen is based on a district heating network relying on heat produced from bioenergy. The biofuel plant was the first large-scale plant in Norway to be used only for district heating. The heating network is a 'standard' district heating system designed to operate at 120°C and 16 bar pressure. It is noteworthy that the temperature remains constant at 110°C from October to May, despite the fact that the airport's de-icing activity is based entirely on district heating. The total heat delivered from the district heating system is 50-60 GWh a year. During an average year, bark and wood chips will replace fuel oil to produce about 35 GWh/year. The energy in forestry residues is also used, avoiding the use of 35 GWh/year of fuel oil. Acquiring the biomass locally minimises the environmental impact of fuel transport. Emissions of dust, carbon monoxide (CO) and nitrogen oxides (NOx) are well below permitted levels. The environmental integration with the local landscape is very good and the building is close to the main road carrying passengers to and from the airport. After the successful operation of this plant, an additional 20-30 small bioenergy plants (1-10 MW) have been built in Norway.

captures solar energy and atmospheric carbon. If there is more carbon in the terrestrial biosphere, there will be less in the atmosphere. Land use change activities such as afforestation, and sustainable forest and farm management practices can increase the carbon content per unit area in vegetation and soils.

Changes in management intensity can also have an impact on carbon stocks, but this should not be the only consideration. In some countries guidelines have been developed with regard to energy plantations to ensure their location and management protect landscapes and habitats, and soil and water quality. The development of conversion plants is usually closely monitored, with widespread adoption of guidelines and regulations concerning operating standards. These standards are usually developed to protect our natural resources, on which our society and its economy depend.



Courtesy R. Matthews, United Kingdom

Figure 5: An illustration of the recycling of carbon as biomass accumulates in energy crops and forests and is consumed in a power station. a: CO_2 is captured by the growing crops and forests; b: oxygen (O_2) is released and carbon (C) is stored in the biomass of the plants; c: carbon in harvested biomass is transported to the power station; d: the power station burns the biomass, releasing the CO_2 captured by the plants back to the atmosphere. Considering the process cycle as a whole, there are no net CO_2 emissions from burning the biomass. (Source: Matthews, R. and Robertson, K. 2002)

Case Study — Ireland: anaerobic digestion of waste

In 1999, the Camphill anaerobic digestion plant was constructed to study the feasibility of using farm and agro-food industrial wastes as a profitable renewable energy enterprise. The installation is located in the Ballytobin Camphill Community, a residential therapeutic centre for disabled children and adults, located on an 8 hectare farm. Wastes feeding the digester come from farms and food-processing industries close to the plant, and the gas is burned in a traditional CHP installation. The solid effluent resulting from the process is composted and sold as organic garden compost. The electricity produced from waste treatment is used for heat and power requirements for the 90 people living in Ballytobin Camphill Community, estimated to be 150,000 kWh of electricity and 500,000 kWh of primary heating energy annually. In addition, employment in a rural enterprise has been created for people with disabilities.

Case Study — Denmark: gasification of woodchips

The Babcock and Wilcox Vølund Up-draft, Single-stage Biomass Gasification Process Demonstration at Harboore, is a success story from Denmark. The programme was initiated in 1989 at a 1 MWth test facility at the Kyndby Power Plant (Sealand), sponsored in part by the Power Utility Company ELKRAFT and the Danish Energy Agency. Based on these results, in December 1993 a nominal 4 MWth woodchips gasifier was built with support from the Danish Energy Agency in Harboore - initially to provide district heating for about 750 subscribers in the municipality. Since 1994, the Harboore gasifier has been in operation for more than 70,000 hours and the two Jenbacher gas engines have delivered more than 3,700 MWh of power to the grid, corresponding to a mean power efficiency of 27%. The gasifier has a proven long-term capacity of 3,700 kWth fuel input and (when hot) it is able to modulate down to a few hundred kWth and back to full load within a few minutes. The ash discharged from the system has a 'total organic carbon' of less than 1% and can be used as a valuable fertiliser. The wastewater discharged is close to the quality of potable water. The municipality of Harboore considers this demonstration plant a success, because the plant is completely fuelled by renewable energy and the environmental impact from the operation and the cost of the district heating supply is favourable in comparison to a state-of-the-art, grate-fired plant.

Harboore biomass gasifier based CHP plant (Courtesy Babcock & Wilcox Vølund)

Social Aspects

Bioenergy offers opportunities for additional value to be derived from products already in the economy. The dispersed nature of most biomass resources lends itself to smaller scale operations of up to 50MW. These are within the capability of communities to feed and operate, creating and retaining wealth within the local economy. For example, 11,250 ha of short-rotation woody crops could supply enough biomass for a 30 MW power station.

New employment opportunities arise in growing and harvesting biomass, transport and handling, and plant operation. They also extend to equipment manufacturers and maintenance crews. Farmers may improve returns as marginal crops become viable given an additional source of income from energy byproducts. Degraded forests may be rejuvenated and waste streams diverted to produce energy. Bioenergy can also contribute to local and national energy security which may be required to establish new industries.

Bioenergy contributes to all important elements of national/regional development: economic growth through business earnings and employment; import substitution with direct and indirect effects on GDP and trade balance; security of energy supply and diversification (Table 2). Other benefits include support of traditional industries, rural diversification and the economic development of rural societies. These are all important elements of sustainable development.

The increased use of bioenergy has stimulated a revival of cultural traditions. In the boreal forest, many remote communities have no year-round road or connections to electricity grids, and are dependent on diesel generators supplied by fuel flown or barged in at high cost. These communities are often surrounded by forest that could provide the necessary biomass for energy generation, making the community more self-sufficient, reducing costs, providing employment, keeping wages and benefits within the community, and generally integrating well with a forest-based culture.

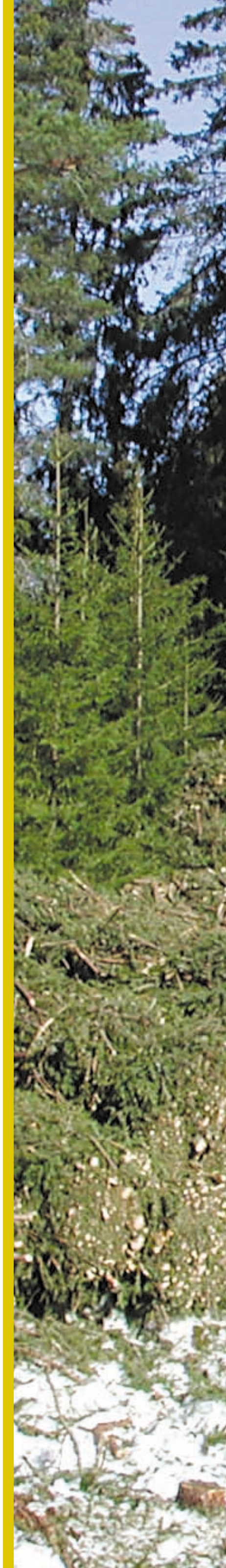
There are many examples of 'urban bioenergy' projects, such as this CHP plant in Enköping, Sweden. (Courtesy P. Westergård, Sweden)

Table 2: UNDP selected indicators of socioeconomic sustainability within the context of modernised biomass energy for sustainable development

Category	Impact	Quantitative indicators
Basic needs	Improved access to basic services	Number of families with access to energy services (cooking fuel, pumped water, electric lighting, milling etc.), quality, reliability, accessibility, cost.
Income generating opportunities	Creation or displacement of jobs, livelihoods	Volume of industry and small-scale enterprise promoted, jobs/$ invested, jobs/ha used, salaries, seasonality, accessibility to local labourers, local recycling of revenue (through wages, local expenditure, taxes), development of markets for local farm and non-farm products.
Gender	Impacts on labour, power, access to resources	Relative access to outputs of bioenergy project. Decision-making responsibility both within and outside of bioenergy project. Changes to former division of labour. Access to resources relating to bioenergy activities.
Land use competition and land tenure	Changing patterns of land ownership. Altered access to common land resources. Emerging local and macroeconomic competition with other land uses	Recent ownership patterns and trends (e.g. consolidation or distribution of landholdings, privatisation, common enclosures, transferal of land rights/free rights). Price effects on alternative products. Simultaneous land uses (e.g. multi-purpose crop production of other outputs such as traditional biofuel, fodder, food, artisanal products, etc.

Case Study **Canada: biomass-fuelled district heating plants**

Prince Edward Island has been one of the most active Canadian provinces in bioenergy and district energy. Three small district heating plants combine to heat provincial government buildings, university, hospital, technical college, shopping malls, and other commercial buildings (84 in total). They provide hot water and steam for heating and electricity, with the surplus electricity sold to the grid. The system also provides energy for cooling to two major customers. Steam that provides district energy to the Queen Elizabeth Hospital is used for air-conditioning through the use of steam absorption chillers. The University of Prince Edward Island also uses hot water for cooling using hot-water absorption chillers. Biomass feedstocks consist of municipal solid waste, woodchips, and sawmill waste, thus alleviating disposal problems while reducing dependence on fossil fuels and the cost of buying electricity.



Economic Aspects

Sources of biomass that are already concentrated in one location, often as a waste product of another process, tend to be cheapest since they require least collection and handling and no crop production costs. Many forest and crop residues are not competitive with fossil fuels when they are dispersed over large areas in small volumes. Costs will be minimised if biomass can be sourced from a location where it is already concentrated, such as at a sawmill or sugar mill, and converted nearby.

The cost of biomass conversion varies according to a range of factors including the types of biomass and conversion process and the scale of operation. The competitiveness of bioenergy will also depend on the availability of alternative energy options, relative costs and prices, and regulatory frameworks. There are emerging markets for environmental services such as carbon sequestration and biodiversity protection. As the policy environment around the Kyoto Protocol develops, for example, the trade in 'carbon credits' will impact on the economics of biomass and alternative energy systems.

There are several policy issues evolving under the umbrella of sustainable development, including energy self-reliance, security of supplies, diversity of sources, sustainable development, clean air and climate change initiatives. Governments have responded to these issues and have introduced many programmes to support renewable energy: cost-sharing research and development, demonstrations for new energy technologies and tax incentives to encourage market penetration, informing the public about the merits of renewable energy, facilitating the development of standards and training tools, and adapting regulations to evolving circumstances. These help to

Small scale solid waste digester, Kompogas, Switzerland.

Case Study: The Netherlands: biomass trade facilitates co-firing

In 2004 the Dutch company Essent opened a new unloading facility on the riverside of its Amer Pulverised Coal-fired Power Plant in Geertruidenberg. It can handle up to 600,000 tonnes of biomass a year, mainly forestry residues (e.g. wood pellets from Canada), and agricultural residues (e.g. palm kernel from Malaysia). The biomass is ground, milled and fed into the boiler as a powder, ensuring a very efficient conversion, with low emissions from the power plant. In this way coal consumption and CO_2 emissions are reduced by as much as 15%.

Unloading facility at the Amer Power Plant in the Netherlands. (Courtesy Essent, the Netherlands)

Amer Power Plant, Geertruidenberg, the Netherlands. (Courtesy Essent, the Netherlands)

Case Study: Austria: rural district heating

Biomass-fired district heating plants in rural areas have become quite common in Austria. By 2003 there were 370 such plants with a total installed capacity of about 2 GW. The picture shows the 2 MW facility in Rankweil (population 11,000) in Western Austria. This plant began operation in 2000 and was awarded the prestigious 'Energy Globe Austria 2002'. At present it is owned and operated by the local 'citizen forest enterprise' - Bürgergemeinschaft - and provides renewable and sustainable heat to 21 public buildings and 61 private households and commercial enterprises. The project helps to rejuvenate the severely over-aged forest of the steep-sloped Laterns valley (more than 70% of the standing stock is older than 140 years), thus reducing the risk of erosion, landslides and avalanches. Moreover, this plant has served as a model for similar facilities that have been erected in neighbouring villages, or are currently in the planning or construction phase.

The wood-fired district heating plant in Rankweil, Vorarlberg. (Courtesy R. Madlener, Austria) address some of the technical, financial, institutional and policy hurdles that have hindered the adoption of increased bioenergy.

Public scepticism of new systems is a common barrier to new ways of doing things. This can be overcome by a combination of public education and information. As society becomes more aware of the nature of environmental risks, real or perceived, we may also feel empowered to act accordingly and make a difference. Modern technology provides the opportunity to rapidly disseminate information to a wide audience. This opens society to new ideas and gives us the opportunity to test ideas in the marketplace. Organisations, among which IEA Bioenergy is prominent, have been created to share information and to promote the adoption of appropriate new technologies.

The Barra Grande alcohol and sugar production plant in Brazil produces ethanol from sugar cane on a commercial scale.

Case Study

Austria: large-scale urban bioenergy

Location of the planned 65 MW wood-fired CHP plant in Vienna. (Courtesy WIEN ENERGIE, Austria)

The municipal energy utility of Vienna (WIEN ENERGIE) and the Austrian Federal Forest Company (Österreichische Bundesforste AG) have recently signed a contract to jointly develop and operate one of the world's largest biomass cogeneration (CHP) plants exclusively fired with forest residues. The new plant will be located at a former fossil-fired thermal power generation site in Simmering, one of Vienna's southern boroughs. Unlike many Scandinavian cities, Vienna has no wood heating tradition, which makes this project special. The installed total capacity of the plant will be nearly 65 MW (15-23 MW_e, ~37 MW_{th}), resulting in an investment of some 52 million Euros. The plant, which will be in operation some 8,000 hours per year, will use about 190,000 tonnes of forest residues annually, and generate electricity sufficient to meet the needs of about 45,000 households and heat for about 12,000 households. The plant is scheduled to commence operation in mid-2006. It is expected to replace 140,000 tonnes of CO_2 from fossil heat and power generation and will feature state-of-the-art wood CHP technology. Given its urban location and significant biomass input requirements, fuel delivery logistics will be an important feature of the project. It is envisaged that most of the forest biomass required will be delivered by train from neighbouring provinces, helping to keep adverse environmental impacts at a minimum.

Summary

Renewable biomass to energy systems address a number of issues faced by industrialised countries. Bioenergy contributes to the maintenance of rural societies, reduction of greenhouse gases, energy security, and protection and conservation of natural resources. Many of the technical barriers to bioenergy use have been overcome; the remaining hurdles are those of a less tangible nature, i.e., financial and institutional. Given a supportive policy environment, bioenergy can provide a sustainable solution to future energy demands. IEA Bioenergy is prominent in the identification and promotion of the production and use of bioenergy, developing sustainable bioenergy systems, encouraging the appropriate use of biomass resources for energy, and increasing the contribution of bioenergy in the overall energy market.

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IEA Bioenergy

IEA Bioenergy assists member countries to expand the use of sustainable bioenergy systems through facilitation, coordination, and demonstration activities. This is accomplished through cooperative research and information exchange, leading to the commercialisation and deployment of bioenergy technologies.

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