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Socio-Economic Impacts of Biomass Deployment for the Production of Heat and Electricity

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Abstract

Today, concerns about the environmental impacts associated with fossil fuel use, particularly the global climate change, have added new immediacy to the development of alternative energy systems. Biomass energy systems are among the alternative systems under development. There is enormous biomass potential that can be tapped by improving the utilisation of existing sources, developing more efficient and advanced technologies to convert raw biomass into easy-to-use carriers (electricity, liquid or gaseous fuels, processed solid fuels) and by increasing plant productivity. Therefore, much more useful energy could be extracted from biomass than at present, bringing significant social and economic benefits to both rural and urban areas and to the environment.

The present thesis attempts to investigate the different renewable sources and to set the main reasons for supporting their use. It focuses on biomass and looks through the technologies used to convert it into useful energy. It tries to evaluate the social, economic and environmental impacts of bioenergy production systems. It presents the obstacles – known as externalities - that still hinder the extensive implementation of biomass energy.

This theoretical approach is followed by the development and trial of a model for the financial evaluation of a biomass project. This is going to be a preliminary tool for planners and developers, used for the evaluation of the financial viability of a biomass project and for the analysis of the social, economic (financial and employment) and environmental impacts of the project in the local economy.

This thesis will conclude that there are significant opportunities related with the development and commercialisation of biomass conversion technologies, the growth of energy crops and their management, and the operation of biomass energy projects. It will also be seen that when rough comparisons are attempted, initial results indicate that biomass energy net external costs may be lower than those of conventional energy sources. In the case of global warming and erosion, particularly, the difference between biomass and coal externalities may account for more than the difference in their production prices.

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Chapter 1 INTRODUCTION

1.1 The picture today

The need for the development of renewable generation mainly arises from the requirement to reduce emissions of greenhouse gases. The United Nations “Earth Summit” in 1992 established the need to control greenhouse gases, recognising the growing concerns of rising levels of global warming and pollution. The Kyoto Protocol, drawn up in 1997, aimed to reduce the emissions of greenhouse gases by developed countries and led to widespread policy support and encouragement for the generation of electricity from renewable sources. The result has been rapid development of renewable technology. In response to the Kyoto Protocol, in August 2001 the European Union published Directive 2002/358/CE, which continued to commit member states to set levels and targets for reducing emissions and increasing renewable energy supply.

In January 2000 the UK Government committed itself to supplying 10% of UK electricity needs from renewable sources by 2010. In February 2003, it released an energy white paper confirming this target and setting an ambition of 20% of electricity from renewables by 2020. The white paper also promotes the reduction of the UK’s carbon dioxide emissions – the main contributor to global warming – by some 60% by about 2050, with expectations of real progress by 2020.

In Scotland, the Executive is committed to rising the overall proportion of electricity generated from renewable sources to 18% by 2010 and has recently consulted on the potential to generate as much as 40% of Scotland’s electricity from renewables by 2020.

In this context, biomass can play an important role in meeting the Kyoto Protocol and the Government’s commitments. Co-firing biomass with fossil fuels and the use of biomass fuels to produce energy in a closed carbon cycle, as a substitute for fossil fuels, is one of the most promising and effective ways for halting the increase of the CO_2 concentration.

1.2 Objectives of the thesis

In the following chapters, an overall appraisal of Biomass as an energy resource will be attempted.

The main objectives of this thesis are:

1. To identify the different renewable energy sources (wind, solar, hydro, biomass etc), how they developed historically and which are their future use potentials.

2. To conduct a literature review on the social and economic impacts of renewable sources.

   By social impacts we mean the impacts on employment, education and health.

   By economic impacts we mean the creation of local industry, the development of infrastructure and skills, the enhancement of the local economy and the competitive development of renewable energy projects in comparison with fossil fuel technology projects.

3. To conduct an in depth literature review on biomass, looking at case studies, magazines, government and EU policies, projects and academic literature.

4. To conduct a study on the socio-economic aspects of bioenergy systems. This will involve:
   - the review of the existing ways of planning the projects
   - the review of the relationship between biomass and society across the EU and in particular in countries with a focus on biomass
   - the investigation of the existing models used to identify and quantify the socio-economic and environmental impacts of bioenergy production systems

5. To conduct a critical analysis of these factors by assessing the state of the art evaluation tools e.g. investigate the factors that all tools take into consideration.

6. To develop a model for bioenergy project evaluation. The model will be easy to use and will facilitate a cost benefit analysis of biomass projects. It will be based on the existing and already tested models and the recommendations derived from the abovementioned review.

Chapter 2 RENEWABLE ENERGY SOURCES

2.1 Introduction

The terms "Renewable Energy" and "Sustainability" have been increasingly used during the last decade. New and renewable energies are becoming one of the world's main energy sources due to their contribution to secure, sustainable and diverse energy supply, the generation of jobs and the development of future technologies. They are playing a substantial role in the medium and especially in the long term.

If we take a brief look at the term Renewable Energy, we'll find the following definitions:

Renewable Energy Sources

Renewable energy sources are those, which are derived from the sun or other natural processes. They are also replenishable by those sources over relatively short time periods. Some examples of renewable energy resources are *sunlight, wind, falling water, sustainable biomass, wave motion, tides, ocean thermal energy and geothermal energy*.

Non-renewable Energy Sources

Non-renewable energy sources are those, which are not replaced or are replaced very slowly by natural processes. Any non-renewable energy resources that we use are not replaced in a reasonable amount of time (our lifetime, our children's lifetime...) and are thus considered "used up", not available to us again.

Primary examples of non-renewable energy resources are *fossil fuels*-oil, natural gas, and coal- and *nuclear power*. Fossil fuels are continually produced by the decay of plant and animal matter, but the rate of their production is extremely slow, very much slower than the rate at which we use them. Uranium for the generation of nuclear energy is not a fossil fuel, but still requires the depletion of finite physical reserves so it is considered a non-renewable energy source.

By the Massachusetts Renewable Energy Collaborative's Ad Hoc Committee on Renewables Definitions May 21, 1997

2.2 Types of Renewable Energy Sources

Most renewable energy comes either directly or indirectly from the Sun. The different energies include:

2.2.1 Solar Energy

Energy from the sun can be categorised in two ways: in the form of heat (or thermal energy), and in the form of light energy. Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses.

The technologies that directly utilise the heat or light from the Sun in the production of electricity or heat include Photovoltaics or PVs (Solar Cell Technology), Solar Thermal Systems (they comprise collectors, receivers and concentrators to focus incident solar radiation onto the receiver) and Direct Solar Heating Systems (these comprise water heating, cooking, space heating and cooling and solar ponds).

Solar thermal technologies use the Sun's heat energy to heat substances (such as water or air) for applications such as space heating, pool heating and water heating for homes and businesses. There are a variety of products on the market that utilise thermal energy. Often the products used for this application are called Solar Thermal Collectors and can be mounted on the roof of a building or in some other sunny location.

Photovoltaics technology (PVs) is a technology often confused with solar thermal and is in fact what many people mean when they refer to "solar energy". PV technology is a semiconductor-based technology that converts light energy directly into an electric current that can either be used immediately or stored, such as in a battery, for later use. PV panels/modules are very adaptable and can be mounted in a variety of sizes and applications; e.g. on the roof or awning of a building, on roadside emergency phones or as very large arrays consisting of multiple panels/modules. Currently they are being integrated into building materials (such as PV shingles, which replace conventional roofing shingles).

2.2.2 Wind Energy

The Sun's heat drives the winds, whose energy is captured with wind turbines. Wind energy is an indirect form of solar energy; 1 – 2 percent of the solar radiation that reaches the Earth is converted into energy in the wind. Winds result from an unequal heating of different parts of the Earth's surface, causing cooler dense air to circulate to replace warmer, lighter air. While some of the Sun's energy is absorbed directly into the air, most of the energy in the wind is first absorbed by the surface of the Earth and then transferred to the air by convection.

Wind energy conversion systems (wind turbines) are designed to convert the energy of wind movement (kinetic energy) into mechanical power. In wind turbine generators, this mechanical energy is converted into electricity and in windmills this energy is used to do work, such as pumping water, mill grains or drive machinery. The electricity generated can be either used directly or stored in batteries.

2.2.3 Biomass

Sunlight causes plants to grow. The chemical energy that is stored in plants (as a result of the photosynthetic conversion process) and animals or in the wastes that they produce is called bioenergy.

$$CO_2 + 2H_2O \leftrightarrow CH_2O + H_2O + O_2$$

Equation for Photosynthesis

Biomass is the name given to any recent organic matter that has been derived from plants or animals, such as wood from forests, residues from agricultural and forestry processes, and industrial, human or animal wastes. In nature, all biomass ultimately decomposes to its elementary molecules with the release of heat. Therefore, the release of energy from the conversion of biomass into useful energy imitates natural processes (but at a faster rate), and this energy is a form of renewable energy.

Converting biomass to fuel can be as simple as cutting trees into small pieces so they can be burned to produce heat or electricity, or as complicated as converting it into a liquid or gaseous fuel (e.g. sugar-cane or cereal crops to liquid fuels such as ethanol).

2.2.4 Hydroelectric Energy

Hydroelectricity is electricity produced by the movement of fresh water from rivers and lakes. This water comes to the rivers as runoff from rainfall. Rainfall is powered by solar energy, which drives complex energy transfer processes in the atmosphere and between the atmosphere and the oceans. The potential (gravitational) energy associated with this water causes it to flow downwards. This downward motion of water contains kinetic energy that can be converted into mechanical energy, and then from mechanical energy into electrical energy in hydroelectric power stations.

2.2.5 Ocean Thermal Energy

A great amount of thermal energy (heat) is stored in the world's oceans. This energy is called Ocean Thermal Energy. The Sun warms the surface of the ocean more than the ocean depths, creating a temperature difference that can be used as an energy source. Ocean Thermal Energy Conversion (OTEC) utilises the temperature difference between the warm surface seawater and the cold deep ocean water to generate electricity.

2.2.6 Wave Energy

Wave power results from the harnessing of energy transmitted to waves by winds moving across the ocean surface. Ocean waves are caused by winds as they blow across the surface of the sea. The energy that waves contain can be harnessed and used to produce electricity. Due to the direction of the prevailing winds and the size of the Atlantic Ocean, the UK and north-western Europe have one of the largest wave energy resources in the world.

2.2.7 Tidal Energy

The energy of the ocean's tides comes from the gravitational pull of the Moon and the Sun upon the Earth. Tidal power utilises the twice-daily variation in sea level caused primarily by the gravitational effect of the Moon and, to a lesser extent the Sun on the world's oceans. The Earth's rotation is also a factor in the production of tides. Tidal power is not a new concept; it has been used since at least the 11th Century in Britain and France for the milling of grains.

But not all renewable energy resources come from the Sun.

2.2.8 Geothermal Energy

Geothermal energy comes from the natural heat of the Earth, originating deep in its molten interior. This heat is stored in rock and water within the Earth (which is forced to the surface in certain areas in the form of hot steam or water, e.g. hot springs and geysers) and can be extracted by drilling wells to tap irregular concentrations of heat at depths shallow enough to be economically feasible. Low enthalpy resources (50°C to 150°C) can be used for heating purposes: large base load demands such as district heating, horticulture, recreational uses such as spas. Medium and high enthalpy resources (> 150°C) are used for electricity production.

Some geothermal resources may be regarded as renewable because they are derived from energy sources deep within the Earth’s interior. The energy source is so large that the rate of depletion by a geothermal energy extraction project is negligible. However, projects based on using the remainder heat stored in shallowly placed igneous rocks may be non-renewable.

2.3 Why support Renewables?

Renewable energy is important because of the benefits it provides. The key benefits include:

Environmental Benefits

Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies, which rely on fossil fuels. The energy use from fossil fuels is a primary source of air, water, and soil pollution. The use of fossil fuels releases carbon dioxide (one of the greenhouse gases) and other pollutants – such as sulphur dioxide, nitrogen dioxide, particulate matter, and lead – that have a significant impact on our environment. These substances contribute to the greenhouse effect and the global warming, both issues that concern scientists and planners today. On the other hand, most renewable energy technologies produce little or no pollution and therefore they contribute to meeting current and longer-term climate change targets (e.g. carbon neutrality) for the reduction in emissions of greenhouse gases.

Energy for our children's, children's children

Renewable energy will not run out. Ever. Other sources of energy are finite and will some day be depleted.

Unlike fossil fuels, renewable energy sources are sustainable. According to the World Commission on Environment and Development, sustainability is the concept of "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" [1]. This is the definition adopted by the United Nations in its Agenda 21 program (1). That means that our actions today to use renewable energy technologies will not only benefit us now, but will benefit many generations to come.

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[1] Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which humans impact on the environment. http://www.un.org/esa/sustdev/agenda21text.htm

Jobs and the Economy

Renewable energy technologies provide investment opportunities and are labour intensive. Most renewable energy investments are spent on materials and labour to build and maintain the facilities, rather than on costly energy imports (oil, gas imports). Jobs develop directly from the manufacture, design, installation, servicing, and marketing of renewable energy products. Jobs even arise indirectly from businesses that supply renewable energy companies with raw materials, transportation, equipment, and professional services, such as accounting and clerical services.

In turn, the wages and salaries generated from these jobs provide additional income in the local economy. Renewable energy companies also contribute to higher tax revenues locally than conventional energy sources.

Renewable energy resources can also provide alternative and additional rural incomes. Some renewable energy initiatives offer authentic and advantageous alternatives to conventional agricultural land use. For example farmers can generate income by letting land for wind power plants, while using the remaining land for farming. Wood and rapeseed can be cultivated as energy crops. These opportunities often occur in rural or undeveloped areas where the jobs are needed most.

Energy security

Every country’s energy security continues to be threatened by its dependence on fossil fuels. These conventional energy sources are vulnerable to political instabilities, trade disputes, embargoes, wars and other disruptions.

2.4 What are the drivers that influence the development of renewables?

Since the 1960s, interest in the environmental and user impacts of the electricity sector has increased and appears to be here to stay. Many policies and programs translate public support for renewables into on-the-ground projects. Clean energy funds are expected to support a wide array of renewables and other, cleaner alternatives, including solar PVs and fuel cells as well as wind, geothermal and biomass energy. Many countries today have passed mandates for the installation of a certain amount of renewable energy.

In addition, environmental regulations covering electricity production have evolved. Examples include the Clean Air Act, which has forced electricity suppliers to incorporate environmental controls into power plants, and the Renewables Obligation (RO), which came into force on 1 April 2002, and requires energy suppliers to meet 10% of their electricity requirement from renewable sources (wind, water, solar, biomass) by 2010. This will prevent the release of about 2.5 million tonnes of CO_2 and will contribute towards the UK Government's commitment to reduce CO_2 emissions by 20% of 1990 levels by 2010.

Additionally, energy technology and market trends have made renewables such as wind an economic choice for utilities and others concerned about unstable energy costs. In Denmark, for example, the output of wind-powered energy will reach the 21% of the country’s electricity production, the highest in the world [2]. Germany today has the world's largest installed base of wind turbines, totalling 12,001 MW (at the end of 2002), which reflects an average growth of 45% a year over the past three years [3]. However, the share of renewables in Germany’s gross electricity production in 2000 was 6%, of which wind energy accounted for only 1.6% [4].

Beyond a narrow cost comparison, fuel-free renewables offer important risk reduction value, particularly when compared to natural gas power plants subject to wild price fluctuations, and even to hydropower that depends on irregular rain and snow patterns.

Competition based on improved services could also promote renewables, mainly for those consumers who require greater reliability in electricity supply. These customers normally cannot afford blackouts due to sensitive computer equipment, high-revenue business operations that can come to a halt or the need for essential services such as medical care. In this case renewables can offer a competitive solution, either by providing base load electricity, or by storing energy in storing devices (batteries, fuel cells) and providing it when necessary.

One conclusion is apparent: there is money in the renewable energy industry, which has to develop both internally and through export markets. At the same time, the industry is young enough so that its early entrants can win today and in the future.

Chapter 3 BIOMASS

3.1 Introduction

As far as renewable energy is concerned, biomass may include all forms of organic matter that can be used as a source of fuels.

This can include trees, arable crops, algae and other plants (trees or herbaceous biomass grown specifically for energy), as well as agricultural (crop residues such as stalks and processing residues such as nut hulls) and forest residues (wood from forest thinning operations that reduce forest fire risk). It may include effluents, sludge, manure (cattle, chicken and pig waste converted to gas or burned directly for heat and power), industrial (green) by-products and the organic fraction of municipal solid waste (OFMSW) (lawn and tree trimmings, wood pallets, construction and demolition wastes).

The following schematic graphs show the life cycle of Biomass (**Figure 1**), from the biomass production (**Figure 2**) and its transportation (**Figure 3**) to the power generation (**Figure 4**). They include the inputs and outputs of every stage of the fuel cycle.

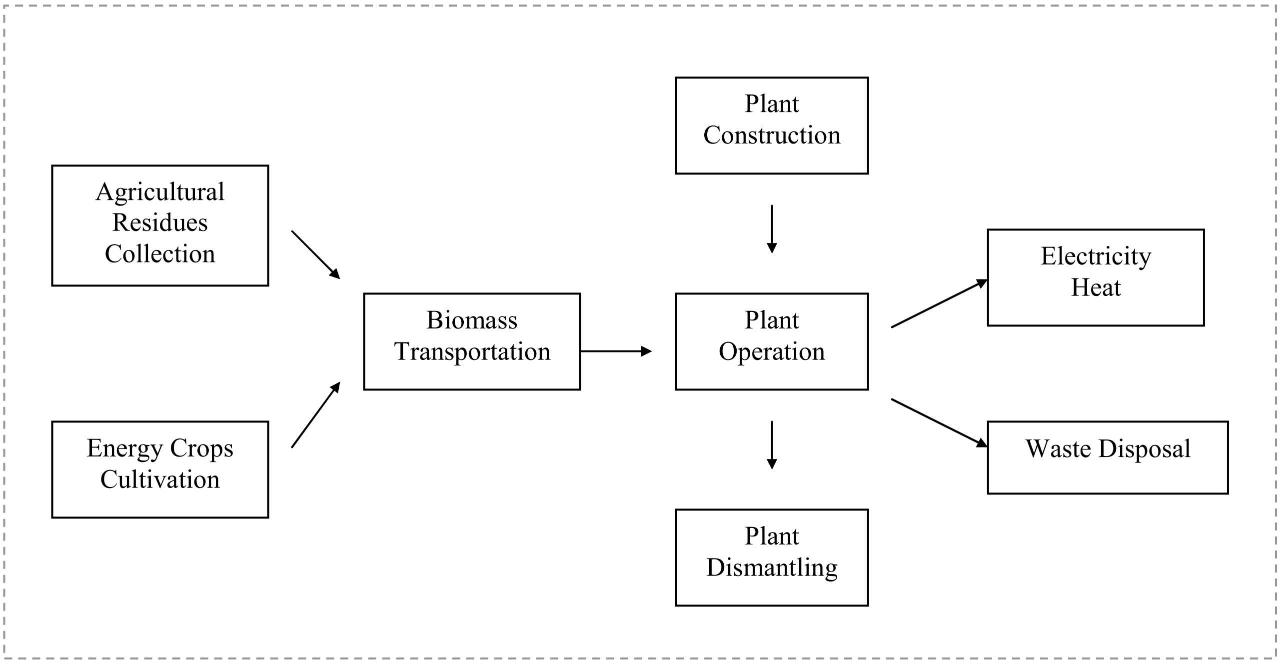

Figure 1 Biomass Fuel Cycle

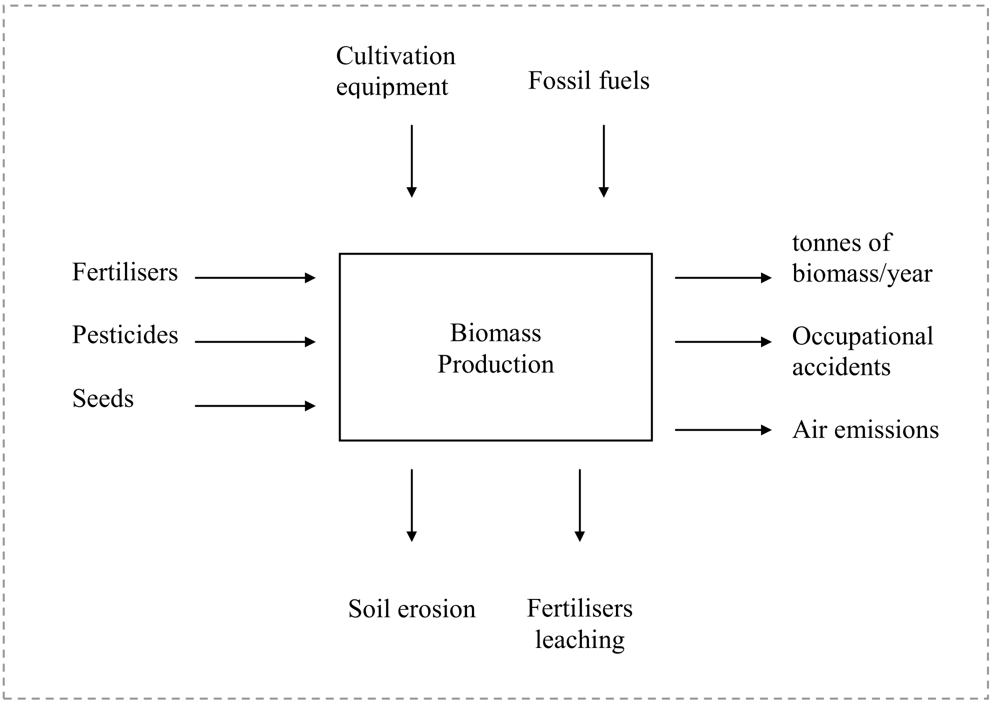

Figure 2 Biomass Production

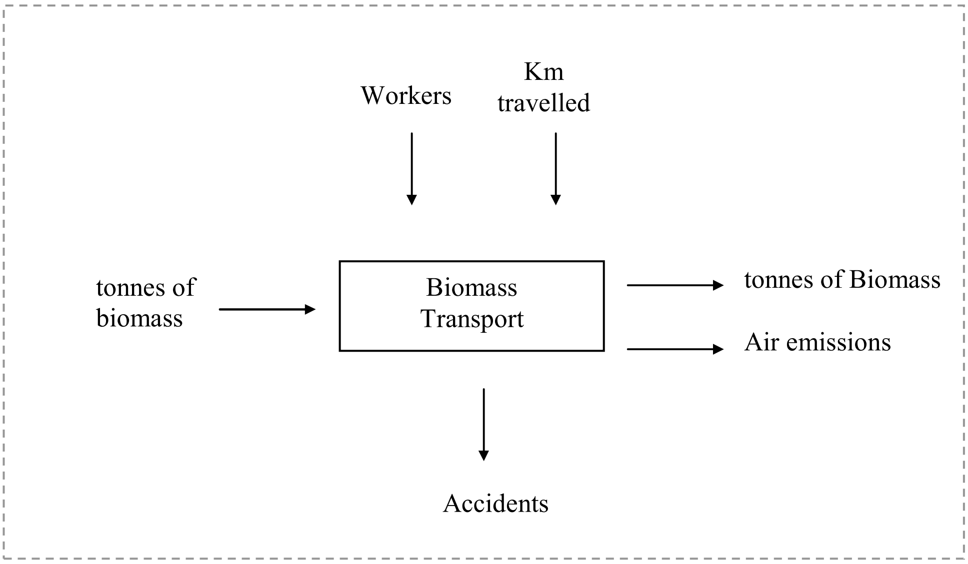

Figure 3 Biomass Transportation

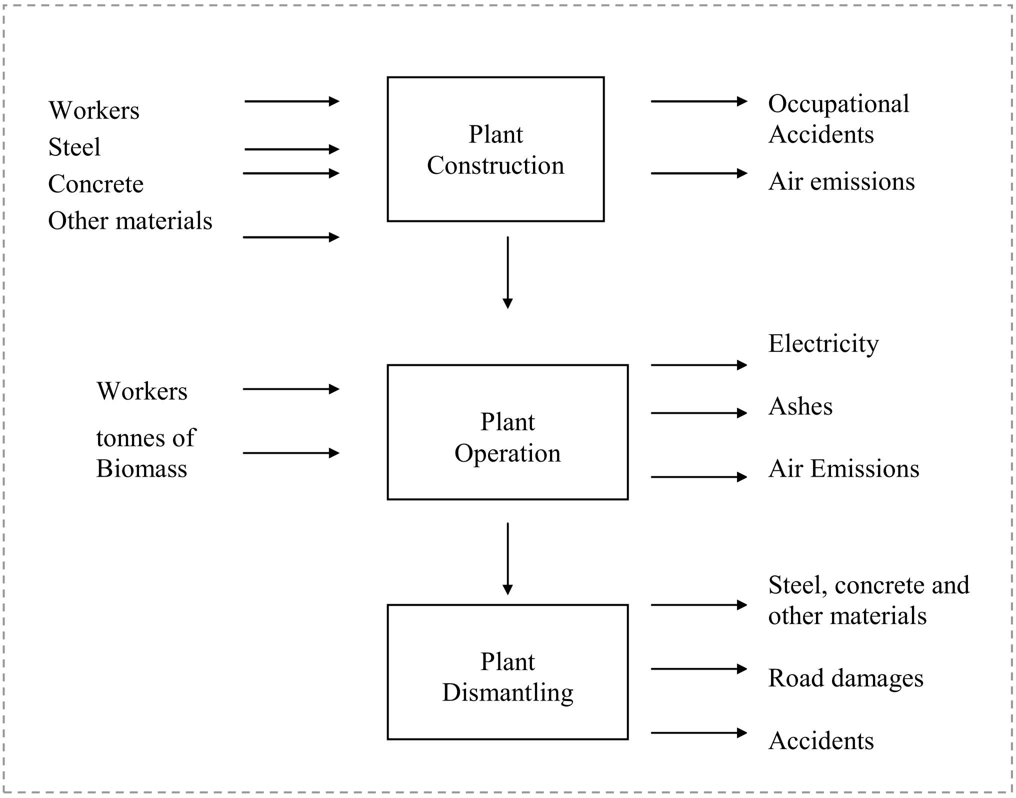

Figure 4 Power Generation

Biomass was the first fuel that mankind learned to use for energy (the first fires of primitive man burning wood for warmth and cooking). Until the 20th century, using biomass to generate heat or to drive steam engines was the most common way to produce energy. However, historical methods of burning wood, field residues, or wood wastes and by-products have tended to be less efficient than modern conversion systems, currently available and in development. Worldwide bioenergy, much of it traditional wood-fuel, is still by far our most important source of non-fossil fuel energy, meeting 13% of primary energy demand. The combination of improved technological efficiencies, scientific advances, increased environmental awareness and environmental protection regulations have turned biomass conversion into a cleaner, more efficient process.

Biomass already contributes 5% of the European Union's energy supply, predominately for heat and power applications. In the long term, biomass's contribution in the EU energy supply may increase to 20%, depending on the policies adopted by the EU in relation to agriculture, sustainability, a secure energy supply and the Kyoto obligations (2).

Some comparisons would be useful at this point as orientation.

- Current UK Electricity consumption is around 300 TWh/year.
- If 1 million ha of land were used for energy crops then this would be capable of generating between 15 and 20 TWh/year.
- To reach a target of 5 TWh/yr by 2010 will need most of the available residues plus 125-175k hectares of energy crops. As a comparison we should note that there are currently 18.5M ha used for agriculture in the UK [5].

Modern bioenergy is clean, efficient and sustainable. The use of home grown resources will reduce the need to import oil and other fossil fuels. Since plants recycle CO_2, the use of biomass contributes to the reduction of emissions that contribute to climate change.

Planting of energy crops on land not required for food production can create new markets and jobs for farmers and foresters (many of whom currently face economic hardship) and improve the local economies and environment. It can establish new processing, distribution, and service industries in rural communities. Using crop residues as fuel resources can improve the economics of farming by reducing disposal costs and providing alternative sources of income. The use of energy crops for power

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[2] The European Commission website on Energy Research, What are the Key Advantages of Biomass? http://europa.eu.int/comm/research/energy/nn/nn_rt_bm2_en.htm

production opens a whole new market for agriculture that has the potential to provide a steady source of income to the farming community.

Biomass can actually improve environmental quality by offsetting fossil fuel use and related emissions and by using wastes that are creating land use problems. As a renewable energy source, biomass offers an alternative to conventional energy sources in the form of rural economic growth, environmental and national energy security benefits.

Some definitions concerning bioenergy are [6]:

“Bioenergy and bioenergy systems” mean all processes in biomass utilisation for energy production from biomass resources (conventional and short rotation forestry, agricultural residues, municipal solid wastes, oil and alcohol-bearing plants), their collection, transport and conversion to end products (transportation fuels e.g. ethanol, biodiesel, heat, electric power, co-generation and solid fuels).

“Social aspects of bioenergy systems” means any impact or contribution of biomass production and use for energy production to employment, education, health and other social factors.

“Economic aspects of bioenergy” means any contribution or benefit of biomass production and use to financial benefits, local industry creation, infrastructure developments and other economic factors.

3.2 Environmental Impacts

The environmental benefits of biomass technologies are among its greatest assets. The issue of global climate change is gaining greater interest in the scientific community. There appears to be an agreement among the world's leading environmental scientists that there is a discernable human influence on the climate and that there is a link between the concentration of greenhouse gases and the increase in global temperatures. Gases such as carbon dioxide, nitrous oxide, ozone, CFCs and methane, allow the Sun's energy to penetrate the Earth's atmosphere and at the same time act as a blanket, trapping the heat radiated from the Earth's surface. The increased emissions of such gases, especially CO_2, by human activities will increase the warming at a rate higher than ever before. The CO_2 emissions from the use of fossil fuels, which provide about 85% of the total world demand for primary energy, cause the observed increase of the CO_2 concentration in the atmosphere.

Co-firing biomass with fossil fuels and the use of biomass fuels to produce energy in a closed carbon cycle, as a substitute for fossil fuels, is one of the most promising and effective ways for halting the increase of the CO_2 concentration. The carbon dioxide released to the atmosphere is recycled back into the regrowth of new biomass. It is more efficient to use land to grow biomass (trees and energy crops) for energy, offsetting fossil fuel use, than to simply sequester CO_2 in forests [7].

Additionally, growing bioenergy crops has important land, habitat and soil conservation benefits; it stops and reverts phenomena like erosion and desertification. Energy crops (perennial plants grown for energy purposes on under-utilised agricultural lands) have an extensive root system that holds soil and minimises erosion, thus improving surface water quality. They can filter agricultural chemicals, keeping them from entering streams, and they can capture nutrients that could migrate into groundwater.

Producing energy from residues in forests, mills and landfills avoids the release of methane into the atmosphere from decomposition of unused wood and agricultural wastes.

One issue that could create a great opportunity for biomass is the implementation of the Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market [8]. Biomass offers the benefit of reducing NO_x, SO_x, and CO_2 emissions and this could create a number of new opportunities for biomass to be used more extensively in industrial facilities and electric power generating plants. The key determinant will be whether biomass fuels offer the least expensive option for a company when compared to the installation of pollution control equipment or switching to a “cleaner” fossil fuel.

3.3 Conversion Technologies

3.3.1 Combustion

We are familiar with the co-combustion of wood or other biomass fuels in coal-fired plants and the combustion of industrial residual wood to generate electricity and heat in the wood processing industry, using combined heat and power. At present, the combustion of biomass for simultaneous generation of electricity and heat in the built environment, coupled to district heating, is taking serious shape. In some counties, particularly in Austria within the EU, many houses are heated with small wood-burning stoves, while larger facilities, with higher efficiencies, show an economy of scale that can best be exploited through distributed heat or district heating schemes, like the ones found in Scandinavia.

Combustion is the complete oxidation of a fuel to carbon dioxide (CO_2) and water. It involves the burning of biomass with excess air, producing hot flue gases that are used to produce steam in the heat exchange sections of boilers. The steam is used to produce electricity in steam turbine generators.

The combustion of wood can be divided into four phases:

- Water inside the wood boils off. Even wood that has been dried for years has as much as 15 to 20% of water in its cell structure.
- Gas content is freed from the wood. It is vital that these gases should burn and not just disappear up the chimney.
- The gases emitted mix with atmospheric air and burn at a high temperature.
- The rest of the wood (mostly carbon) burns. In perfect combustion the entire energy is utilised and all that is left is a little pile of ashes.

At biomass combustion, the energy (heat) that is released can be used for water or space heating or for the generation of electricity in steam turbines.

The combustion of solid fuels will generate ash and other components, such as sulphur and nitrogen, which contribute to the formation of potential atmospheric pollutants. The amount of these compounds depends on the composition of the fuel used and the way in which it is burnt. In simple stationery grates, temperatures may be too low and air supply not enough for complete combustion, which can lead to unburnt material entering the flue. The release of significant levels of such materials into the atmosphere is not acceptable.

The recent emphasis on developing combustion equipment for biomass is caused by the discussion about the global warming (because of CO_2 emissions) and the opportunity to avoid these emissions by using energy crops with a closed CO_2 circulation. This does not mean that CO_2 is not emitted during biomass combustion, but that the whole procedure of crop cultivation, collection, transportation and power generation through combustion is CO_2-free, since plants recycle the CO_2 emitted. Comparing biomass with coal, the former contains a higher proportion of oxygen and a shorter one of carbon.

Biomass combustion to produce energy can be cost-effective and addresses major environmental issues such as waste disposal and climate change.

3.3.2 Pyrolysis

Biomass pyrolysis refers to a process where biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils, tars, high molecular hydrocarbons and water), and gases (mainly CO_2, H_2, CO, CH_4, C_2H_2, C_2H_4, C_2H_6, benzene, etc). Char - more commonly known as charcoal – is a fuel that has about twice the energy density of the original and burns at a much higher temperature. By changing the rate of heating and the final temperature it is possible to modify the proportions of the gas, liquid and solid product.

The method of wood conversion to charcoal by slow pyrolysis (slow heating rate) has been practiced for many years. This requires relatively slow reactions at low temperatures to maximise solid char yield.

Fast pyrolysis (more accurately defined as thermolysis) is the process in which biomass is rapidly heated to high temperatures in the absence of air (specifically oxygen). The biomass decomposes into a combination of solid char, gas, vapors and aerosols. When cooled, most volatiles condense to a dark brown liquid, which has a heating value about half that of conventional fuel oil. While it is related to the traditional pyrolysis processes for making charcoal, fast pyrolysis is an advanced process that is carefully controlled to give high yields of liquid.

The oil, which is easier to store and transport than solid biomass material, is then burned like petroleum to generate electricity. Pyrolysis can also convert biomass into phenol oil, a chemical used to make wood adhesives, moulded plastics and foam insulation.

Liquid fuel production by fast pyrolysis is a promising technology. High yields of liquid products can be obtained under optimised conditions: very high heating and heat transfer rates that require a finely ground biomass feed (2-5 mm), carefully controlled temperature of around 500°C and rapid cooling of the pyrolysis vapours to give the bio-oil product [9].

3.3.3 Gasification

At biomass gasification, biomass is heated in an oxygen-starved environment and is converted into a gaseous fuel, with medium or low calorific value. This conversion of biomass to a gaseous fuel (biomass gasification) generally involves two processes.

The first process, pyrolysis, releases the volatile components of the fuel at temperatures below 600°C through a set of complex reactions. These vapors include hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tars, and water vapor. Because biomass fuels tend to have more volatile components (70-86% on a dry basis) than coal (30%), pyrolysis plays a larger role in biomass gasification than in coal gasification. The byproducts of pyrolysis that are not vaporised are referred to as char and consist mainly of fixed carbon and ash.

In the second gasification process, char conversion, the carbon remaining after pyrolysis undergoes a gasification reaction (i.e. steam + carbon) and/or combustion (carbon + oxygen). It is this combustion that provides the heat energy required to drive the pyrolysis and char gasification reactions. Due to its high reactivity, all of the biomass feed, including char, is normally converted to gasification products in a single pass through a gasifier system.

The biogas produced can be used as a fuel for the generation of heat and electricity but also as a synthesis gas in the chemical industry. The gas produced is usually contaminated with tar and dust that should be removed first. This can be done by using a rotating particle separator, which integrated in the gasification process, removes particles from the gas flow in a very efficient manner.

Energy generation by way of gasification is a very promising technology because of its high efficiency, the relatively low costs and the low emissions.

3.3.4 Anaerobic Digestion

Nature has a provision of destroying and disposing of wastes and dead plants and animals. Tiny microorganisms called bacteria carry out this decay or decomposition. The manure and compost is also obtained through decomposition of organic matter. When plant or animal matter decomposes at the bottom of water or shallow lagoons then bubbles can be noticed rising to the surface of water. This phenomenon is the decomposition process that takes place under the absence of oxygen. The gas produced (Marsh gas) is a mixture of methane (CH_4) and carbon dioxide (CO_2) and is commonly called Biogas. The technology of harnessing this gas from any biodegradable substance (organic matter) under artificially created conditions is known as biogas technology.

Anaerobic digestion, like pyrolysis, occurs in the absence of oxygen. In this case, though, bacterial action rather than high temperature causes the decomposition. It is a process that takes place in almost any biological material, but is favoured by warm, wet and of course airless conditions. Anaerobic digestion also occurs in situations created by human activities. One is the case of biogas generation in concentrations of sewage or animal manure, and the other is the landfill gas production by domestic refuse buried in landfill sites. The process of biogas production is complex. What happens is that a population of bacteria breaks down the organic material into sugars and then into various acids, which decompose to produce the final gas, leaving a residue whose composition depends on the type of system and the original feedstock.

3.4 Conclusions

Worldwide, millions of people rely on biomass as an energy source. However much of it is still used in fairly simple, and sometimes polluting, combustion systems that are not very energy efficient. In order to achieve the targets set (increased use of biomass) and contribute to sustainable solutions there is a need to understand the present position and identify the main areas where further research and development can improve efficiencies and lower the costs. Many biomass technologies are now available on the market and more are being developed and optimised, so that biomass sources can be used more efficiently.

Chapter 4 Social and Environmental Dimensions of Bioenergy

4.1 Introduction

In the general social and economic contexts, energy systems form an integral part of the society. Seen from that perspective, their planning and implementation should be performed accordingly. The availability of energy is a basic requirement for most tasks in a modern society, both in the domestic life and for the business, commerce and the service sectors. Energy generation and distribution may cause annoyance, environmental dangers, occupation of space and other disturbances on the interest of other stakeholders. Money, once spent for energy, cannot be used for other alternative reasons.

In the last decades it has become more obvious that the apparent value of energy supply in the social perspective goes further than the money price per kWh or GJ. Based on this wider range of values, individuals, groups and decision takers are prepared to put preference on some energy systems before others. In this context, renewable energy is often preferred, but the preference should also comprise aspects like local jobs and local income creation and other socio-political characteristics like transparency and direct democratic control.

Worldwide, biomass ranks fourth as an energy resource, accounting approximately for 15% of the world's energy supply. For some developing countries, however, biomass accounts for approximately 90% of their energy supply, making biomass the only available and affordable source of energy [10]. In the European Union, biomass has the greatest potential, among renewable energies, to supply a large amount of energy, in the short and medium term. Its energy may be used for heat, electricity or transport and so it is expected to be the largest contributor to the EU objective of achieving 15% of its primary energy requirements with renewable energies by year 2010 [11].

Increased bioenergy use, especially in industrialised countries, will depend on greater exploitation of existing biomass stocks (particularly residues) and the development of dedicated feedstock supply systems.

There is much optimism that biomass will continue to play an important, and most likely increasing, role in the world's future energy mix. This is because:

- Biomass's productivity is an order of magnitude greater than the world's total energy consumption [12]

- Bioenergy can be produced and consumed in a clean and sustainable manner, thus offering important environmental benefits (CO_2 and other pollutants reduction, which helps to fulfil the international agreements on limits for emissions)

- The research on advanced biomass power technologies is increasing and expanding on several fronts

- Electricity generation from biomass offers socio-economic benefits from re-deployment of surplus agricultural land

- The use of biomass supports the decentralisation of energy production that does not rely upon constrained transmission and distribution grids and offers a steady and secure supply of domestic fuels

- Biomass is strongly supportive of EU policy in areas such as Agriculture, Energy and Regional Development and has the potential to support Employment policies

- Direct employment occurs in rural communities supplying biomass

- Biomass can largely be produced and used without major technological investment, which is of particular importance to less developed countries

- Small-scale, localised heat and power supply from biomass develops local energy security and diversity of energy supply, as well as supports the development of local enterprises

- At a wider level, EU manufacturers and suppliers of biomass electricity technology become players in the world market

- The use of biomass gives value to previously non-merchantable resources

4.2 Externalities

However, there are still quite a lot of obstacles for an extensive implementation of biomass energy. One of the most important ones is its cost. At present, private costs for bioelectricity are higher than for other energy choices, so there are no incentives for its production. But it has to be repeated that *energy options should not be measured only on a private, economic basis*. Preferring one option to another may have consequences on several aspects of society and the environment. These consequences should be taken into account if we want to reach the higher profit for society.

These consequences on society and the environment, which are not accounted for by the producers and the consumers of energy, are named *externalities*. For example they include damage to the natural environment that traditional economic assessments of fuel cycles have ignored up to now. They are produced whenever production procedures, or consumers' utility, are affected by variables not controlled by themselves, but by other economic forces [7]. The effects may be positive (external benefits) or negative (external cost).

Externalities represent costs or benefits not assigned to their responsibles, and therefore not considered by the market. This produces a market failure, as the price (which is the market assignment tool) does not account for all costs and benefits. This, in turn, produces an inefficient assignment of resources. If, for example, an external benefit exists, the price will be higher than its optimum, and thus the quantity produced will be lower than the optimum. In order to correct this failure, externalities have to be incorporated (internalised) to the cost analysis. However, before their internalisation, they must be quantified and expressed in monetary units.

Economists have struggled to put a market value on products and services not traded in any market. Environmental scientists have difficulty quantifying environmental impacts. The fact that the values placed on economic and environmental benefits and costs will defer at each scale of analysis makes the valuation of economic and environmental tradeoffs more complicated. The scales usually used to evaluate these tradeoffs are: 1) the individual firm level (the conversion plant), 2) the community level (the relations between the plant and the associated goods and service providers and the impacts on the regional infrastructure) and 3) the national level (the relations between all the firms and consumers and the effect on national institutions).

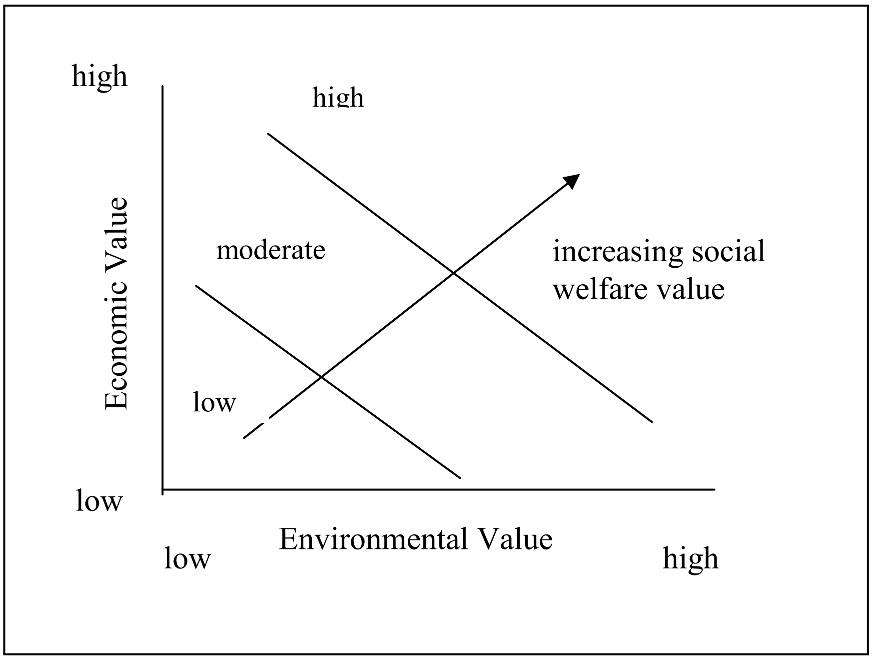

Figure 5

On the above Figure 5 the way in which the social value depends on the economic-environmental relation is depicted [13]. It is easy to understand that the higher the environmental and economic values are, the higher the social value will be. The graph shows that when the economic and environmental values rise together, then the social welfare value rises as well, as a result of the high appreciation given to both the other factors. The social value moves through three different zones- of low, medium and high social values- the way the arrow demonstrates.

ExternE Project

In 1991, the European Commission in collaboration with the US Department of Energy (US DOE) launched the ExternE project. This is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles. So far, the project has successfully developed the methodology, assessed many different fuel cycles (coal, oil, gas, nuclear, hydro, photovoltaics, wind, biomass and others) quantifying their impacts and their evaluation in monetary terms, and identified the key externality issues for future policies.

4.3 Types of externalities

Some externalities associated with the biomass fuel cycle and addressed in the study are:

4.3.1 Macroeconomic effects

Macroeconomic effects refer to economy wide outcomes. The implementation of a power plant produces effects in the rest of the economy because of the increase in demand of goods and services created by the spending in the project.

4.3.2 Employment

The increase in biomass use creates employment, and in particular may provide initial routes into employment for the socially excluded or the low skilled. However, at the same time, the increased use of biomass for the production of electricity and/or heat may lead to the loss of (potentially higher quality) jobs in other sectors of the economy.

To understand how employment effects can be better taken into account it is necessary to recognise the various levels at which impacts may take place. The increased use of biomass can have both positive and negative direct effects. Expenditure on biomass generates direct employment in carrying out biomass production activities. This employment may arise either in specialised firms or in companies in other sectors. Such expenditure may also have direct negative effects for electricity generators from fossil fuels. For them, increased use of biomass could potentially reduce market share, lower output and potentially reduce employment.

Indirect effects result from changes in direct employment and can also be either positive or negative. If direct employment increases, then there is a ‘multiplier’ effect because those people directly employed spend their salaries on goods and services. This can create additional employment in the sectors supplying those goods and services (or reduce employment if direct employment decreases). However, if increased expenditure of biomass means that there is less expenditure in other sectors, then jobs in those sectors may be lost. This is known as a ‘crowding-out’ effect. The interaction between the direct and indirect effects changes the structure and composition of the overall demand for labour in the economy. This is termed as the net macroeconomic effect. Whether there is a net increase or reduction in aggregate employment depends upon two key factors. Firstly, whether biomass activities are more labour intensive than other activities, so that expenditure on biomass results in more jobs than equivalent expenditure elsewhere. Secondly, whether biomass expenditure feeds through into higher product prices and lower real wages, which may affect labour supply.

Direct employment in bioenergy plants includes the jobs at the plant level and in the agriculture industry and in the manufacturing and associated industries. Direct job creation related with the conversion plant can be measured fairly easily by determining the number of workers needed to build and operate the plant.

Indirect employment is that created elsewhere by the net flow of expenditure generated by the project (changes in the purchasing activities of the renewable and conventional energy technologies). It is more difficult to measure the number of indirect jobs that may be created in associated supply and support industries.

The employment effects are usually measured in full time equivalents (FTE), which are calculated by adding the full time-workers with the part-time and seasonal workers (weighted according to the number of hours they work per year).

4.3.3 CO_2 Fixation

This may be the most controversial effect to value, because of the uncertainty of the global warming process itself, and of the effects it may produce. The valuation of the absorption and emissions of CO_2 for the whole biomass fuel cycle (the result is a net CO_2 absorption, because of the carbon fixation by the energy crops) can be made using literature values for the damages caused per tone of CO_2 emitted, ranging from 2.18 to 15.45 Euro per tonne [14]. Major caution has to be given to the assumption that the negative impact of emissions will equal the positive impact of the absorption.

4.3.4 Erosion

The energy crop cultivation creates soil losses. The soil is then carried by the water into watercourses and reservoirs, altering water flow and storage capacity and causing damages.

The valuation of these effects is quite difficult, because of the complexity of the processes involved.

4.3.5 Health Effects

The health effects considered are those created by atmospheric pollutants, such as SO_2, NO_x, CO, NH_3, ozone and particulate matter, radionuclide emissions, occupational health issues (disease and accidents). It is not easy to quantify these effects, since their modelling is very complex.

4.4 Conclusions

The conclusions drawn form the study are that when a rough comparison is attempted, preliminary results suggest that biomass energy net external costs may be lower than those of conventional energy resources. If coal is taken as an example, it may be seen that negative impacts of biomass, except for non-point source pollution, are lower, while positive impacts are higher. In the case of global warming and erosion, the difference between biomass and coal externalities may account for more than the difference in their production prices.

Therefore, we may sum up saying that, in spite of the great uncertainty that surrounds the assessment of externalities, it seems that the total cost of producing electricity from biomass is lower than that of producing electricity from fossil fuels, mostly because of the environmental benefits and the employment created. This costs competitiveness should promote a larger implementation of biomass energy.

Chapter 5 Employment and Bioenergy

5.1 Introduction

A study made from the Renewable Energy Policy Project (REPP) in 2001 states that sharp declines in coal mining will continue, cutting the average labour requirements to fuel and operate coal power plants by 17% from 1998 to 2008 alone [15].

On the other hand, renewable energy sources, such as solar wind and biomass, offer a diverse array of jobs and they also tend to offer more jobs than coal power. Studies and surveys show that renewables are growing, especially biomass due to its ability to run as often as fossil fuel plants and provide base load power.

Technology	Total Shipments/ Installed Capacity in Most Recent Year of Data	Shipments/Installed Capacity in Previous Year of Data	Annual Growth (in %)
PV	288 (2000)	201 (1999)	43%
Wind	17,300 (2000)	13,500 (1999)	28%
Biomass	14,000 (1998)	N/A	N/A
Geothermal	7,974 (1999)	6,797 (1995)	3%

Table 1: The growth in renewable energy industry worldwide (in MW) (3)

Table 1 indicates that the market growth for renewable energy technologies is very real. In labour terms this means jobs.

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[3] See above reference 16.

	1995	2000	2005	2010	2015	2020
Capacity (GW)						
Biomass Liquid (GW eq.)	0.15	0.75	3.88	7.68	11.23	13.42
Biomass Anaerobic	8.12	10.19	16.08	21.58	24.66	26.77
Biomass Combustion	170.09	181.58	204.27	221.28	232.97	236.33
Biomass Gasification	1.64	1.86	3.92	5.38	6.15	6.36
Output (TWh)						
Biomass Liquid	1.21	5.93	30.00	58.40	85.53	102.14
Biomass Anaerobic	19.43	30.01	57.15	82.94	97.32	106.92
Biomass Combustion	367.51	412.76	496.33	562.90	611.22	630.61
Biomass Gasification	6.56	8.14	20.95	30.20	35.03	36.37

Table 2: Predicted capacity and output of Biomass technology in the EU members to 2020 [16]

Table 2 shows that the largest overall increase comes especially from biomass combustion and anaerobic digestion of liquid wastes, providing electricity, heat and co-generation outputs.

5.2 What kind of jobs does biomass create?

The study “The impact of renewables on employment and economic growth” [17], which was carried out to evaluate and quantify the employment and economic benefits of renewable energy in the EU, shows that ‘Renewable Energy technologies are in general more labour intensive than conventional energy technologies, in delivering the same amount of energy output’. It also results that ‘the vast majority of employment is created in biomass technologies, together with biomass fuel provision’.

	2005	2010	2020
Bio Anaerobic	37,223	70,168	120,285
Bio Combustion	15,640	27,582	37,271
Bio Gasification	78,524	96,026	117,151
Liquid Biofuels	10,900	32,369	48,709
Energy Crops	33,527	56,472	79,223
Forest Residues	133,291	139,421	147,170
Agricultural Waste	140,823	220,645	288,971

Table 3: Impact on employment (new net FTE (full time equivalent) employment relative to base in 1995) [17]

The analysis made for this study predicts that biomass use for power, heat or biofuels has the potential to create 323,000 jobs, together with a further 515,000 jobs through provision of fuel as energy crops, forestry or agricultural wastes.

Of course different renewable technologies have different labour requirements. The solar (photovoltaic and solar thermal) and wind technologies in particular generate net positive employment from Construction and Installation. On the other hand, other renewable technologies, such as hydro, require only low levels of maintenance, so their net employment from O&M can be negative. In contrast, a large amount of labour is needed to operate a biomass plant and to collect and deliver the biomass fuel to the plant, therefore the full time equivalent in O&M for both these operations is highly positive for the short, medium and long-term predictions.

Labour requirements for biomass plants include the site and building design and construction, the energy system design, the construction and transportation of the system equipment, the installation of the equipment and the installation of the piping system (in case of heat production and distribution). The Operation and Maintenance of the plant includes the fuelling (in case the system is not automated) of the plant, the periodic checking and replacement or repair of 'wear items' of the equipment and the cleaning of the system.

The process of fuelling biomass energy plants involves three major steps: the biomass collection, its transportation and the energy conversion.

The first step involves all the activities associated with the biomass growth and collection. According to what kind of biomass is used, the plantation and growth of the biomass may not be necessary. For residues and wastes, like mill residues, urban and silvicultural wood waste and agricultural residues, the collection and processing of the fuel are the only activities in this step.

Mill residues from paper, lumber and wood product operations need to be chipped, while sawdust is fine enough for burning. Urban wood waste (commercial, municipal and industrial solid waste) contains many different wood by-products, which need to be sorted before being used as a fuel, as they may be toxic. Acceptable forms of wood waste biomass are pallets, shipping containers and used railroad ties. Silvicultural wood waste (forest thinnings from commercial operations and forest management) can be processed from government agencies, forest companies and speciality companies, which chip the waste on the site of their operations or collect the products and chip them at wood yards. Finally, agricultural residues, such as corn stover and orchard prunings, can be collected and processed on-site or in special yards and fed to the plants.

On the other hand, farmers can grow energy crops on special plantations. The most common crops planted are poplar, willow (they are both tree crops) and switchgrass (it is a herbaceous crop). In this case the collection includes all the activities associated with agriculture, like field preparation, planting, crop maintenance and harvesting.

The second step- the biomass transportation- involves the haulage of the biomass fuel to the power plant. A general rule is that truckers transporting biomass should not travel more than 80 to 120 km (50 to 70 miles) from the biomass source to the power plant, otherwise the biomass becomes too expensive for power generation.

The final step involves the energy conversion. Once the biomass arrives at the plant, operators unload, stockpile and process it. Once it is ready for use, it is fed in the conversion system.

The study mentioned in the introduction [6], concludes that for energy crops and silvicultural wood waste, farmers (for energy crops) and equipment operators (for silvicultural wood waste) garner the most work, with the relative labour requirements for truckers and plant operators depending on project-specific conditions. For urban wood waste, relative labour requirements among different occupations vary according to project-specific conditions.

5.3 Multipliers

Economic impact analysis relates particular economic activities to economic measures such as spending, employment, labour income and tax revenue. Economic activities such as manufacturing, tourism and healthcare generate spending in a local area, and cause jobs to be created that pay income to area residents and generate tax revenue that flows to government. However, quantifying these effects can be difficult, and the calculated economic impact should be considered an estimate based on the best information available at the time.

It is evident that more revenue coming into local businesses results in their ability to hire more employees. Therefore, in addition to the direct jobs created by an economic development project, a number of indirect jobs will also be created. While these jobs may be at different pay scales and require a wide range of skill levels, they may all be directly attributed to the increased economic activity taking place in the community as a result of the new development project. In economic development we call this the concept of "Employment Multipliers".

Some Definitions of the **Employment Multipliers** are:

The employment multiplier "is equal to total (or increase in) employment in both basic and service activities (direct plus indirect plus induced employment) divided by total (or increase in) basic employment (direct employment change)." [17]

"The employment multiplier associated with a particular regional economic stimulus is designed to yield an estimate of the total employment attributable to the stimulus per job or man-year of employment directly created." [18]

Although multipliers can be used to provide ‘order of magnitude’ estimates of the growth in output or income, their use demands some care. Multipliers assume that all additional spending is new spending (rather than transfers from one set of goods and services to another) and, therefore, acts as a net addition to real output. Where expenditure is not new but a transfer, then multipliers will overestimate effects on both output and employment.

Another measure of the economic development is the Multiplier Effect. The difference between the Multiplier and the Multiplier Effect is that the multiplier is simply a ratio and not an absolute number, while the multiplier effect refers to the number of jobs (or the amount of income) supported or created by the basic jobs (or income). So, to identify the multiplier effect, we need to multiply the basic jobs (income) by the multiplier and then deduct the basic employment (or income), since the "effect" should not include the "stimulus".

Theoretically, the total economic impact of an event can be separated into three different types of effects, the direct, the indirect and the induced. The direct is the *immediate effect* after the change in final demand, which is a change in the supply of the product by the same amount. Once the immediate effect has taken place, the demand for inputs to produce the additional output will in turn cause additional demand for the products. This is the indirect effect. When output is increased there is an increase in compensation of employees and other incomes, which may cause further spending and, in turn, further changes in final demand. This is the induced effect of the change in final demand.

The multiplier effect can be seen as a result of spending. This multiplier is called income multiplier and measures the change in income that occurs throughout the economy as a result of a change in final demand. The income multipliers show the ratio of the direct, indirect and induced income changes to the direct income change.

For example, ten pounds spent by a visitor at a local restaurant counts as a direct effect of ten pounds. This direct spending has the advantage that it can be counted relatively easily, but it does not capture the "multiplier effect" of the additional economic activity set in motion by the purchase of the meal.

To the direct effect must be added the indirect effect of spending. In order to produce the ten-pound meal, the restaurant must purchase certain inputs from other businesses. To the degree that these inputs are local, these purchases represent extra local economic activity. For example, the restaurant may purchase two pounds worth of food inputs from the local market for every ten-pound meal sold. The seller at the market may have paid a local farmer one pound for the goods that are then sold to the restaurant, and the farmer may have paid 10 pence for local inputs into the farm. The indirect effect measures the cumulative local purchases from other businesses that are generated from the ten pounds spent on the meal. Because much of this spending goes either immediately or in the end to businesses outside the region, this indirect effect tends to be smaller than the direct effect. A reasonable estimate of the indirect effect of a ten-pound meal might be five pounds.

To the direct and indirect effects must be added the induced effect, which measures the additional spending that occurs across the economy because of the income paid by all of the businesses involved, directly or indirectly, in producing the meal. There is a flow of salaries received by the waiters, cooks, produce store clerks, and others who play a part in putting that meal in front of the visitor. These people receive their salaries and they spend most of them and save some. To the extent that their spending generates jobs in the local economy, there is additional economic impact attributable to the meal. However, a big amount of these salaries may go to a mortgage or car payment that leaves the local economy. In fact, most of the grocery store spending will leave the local economy to pay for food produced elsewhere in the country. But the part that pays the local banker managing the car loan, or the employee at the local store, represents a local economic impact of that ten-pound meal. A reasonable value for the induced effect might be three pounds.

Therefore, the total local economic impact of the ten pound meal would be eighteen pounds, representing the initial purchase (the direct effect), plus the local purchases made from other businesses in producing the meal (the indirect effect), plus the local purchases resulting from the spending by households who received salary income while producing the meal (the induced effect). Here, "the multiplier" is said to be 1.8, meaning that every pound spent on that category (restaurant meals) has a total impact of £1.80 on the local economy after the direct, indirect and induced effects are measured.

The multiplier effect can also be seen in the number of jobs, for example when a company is opening. The hypothetical opening of a company employing 100 people on a full-time basis is considered. The 100 new jobs created is the direct effect of the opening of the company. The number of the indirect and induced jobs can be calculated by multiplying the direct increase in jobs by the employment multiplier. If this is 1.368, then the direct, indirect and induced jobs created by the opening of the company are 137. As we have already the direct increase, we estimate that the indirect and induced jobs are 37 (full-time equivalent). The number of jobs created includes those employees working directly in the company, people working for companies that support operations of these businesses, and those who become employed as a result of the salary base associated with the specific industry.

In order to say that the multiplier has a specific value (e.g. 1.8 versus some other number like 1.2 or 3.7), the various statistical organisations use historical data and tables, specific to each region in the country, to describe how goods and services are produced in each of them. These tables show the amount of inputs from other industries used to produce one pound's worth of output in a particular industry and are called input-output tables. Analysts use these tables to create models to calculate the multiplied impact, or total economic impact, of an economic event.

5.4 Conclusions

The Multipliers provide a picture of the flows of products and services in the economy. They illustrate the flows between various industries and also between industries and the Final Demand sectors- consumers, government, investment, stocks, tourists and exports. The ability to quantify the multipliers and the multiplier effects is important, as it allows economic impact analyses to be carried out. Great research and analysis has gone into tracking the employment multipliers for various industries. And while some industries may result in more indirect employment than others, the fact is that all economic development projects will result in some level of indirect employment. The employment and income multipliers are the most commonly used. This is due to their use in economic impact analyses, which are preoccupied with the employment effects and the change in income (salaries, profits etc.) that occur throughout the economy as a result of a change in final demand.

Chapter 6 The Energy Model

6.1 Introduction

The previous chapters formed the introduction to the Renewable Energy Sources in general and Biomass in particular. They provided information on the different resources and the drivers that influence their development, concentrating specifically on biomass and its interactions with the environment and the society. After having examined the various aspects of the biomass utilisation in energy production and before moving on to the analysis of the socio-economic model, it is sensible to sum up with the benefits and the barriers that biomass use faces today.

Benefits	Barriers
• Biomass provides not only food but also energy, building materials, paper, fabrics, medicines and chemicals	• Despite its wide use in developing countries, biomass energy is usually used so inefficiently that only a small percentage of its useful energy is obtained
• The collection of fuel from forestry and agriculture and the use of energy crops is a sustainable activity that does not deplete future resources	• Limited experience, lack of technical expertise locally, lack of access to financial resources and information on technical options are the most common barriers in biomass utilisation
• Biomass offers considerable flexibility of fuel supply due to the range and diversity of fuels which can be produced	• It is essential to develop a market for biomass with attractive prices for users as well as suppliers, since so far biomass energy is more expensive than energy based on fossil fuels
• The production of electricity and/or heat from biomass helps decrease the CO_2 emissions	• The development of biomass plants in the cities increases the concentration of small particles in the air, that are the cause of respiratory problems

• Biomass use increases the farm income and market diversification, reduces the agricultural commodity surpluses and derived support payments, enhances the international competitiveness and revitalises the retarded rural economies	• The efficient use of firewood requires efficient ovens and basic knowledge of the users. Using wood-chips requires equipment for producing the wood-chips, storing, drying, and feeding into an appropriate boiler. This production-chain should be set up locally for successful use of wood-chips for heating
• The use of biomass can help mitigate climate change, rehabilitate degraded lands, reduce acid rain, soil erosion, water pollution and pressure on landfills, provide wildlife habitat, and help maintain forest health through better management	• The “food versus fuel” controversy argues that energy-crop programmes compete with food crops in a number of ways (agricultural, rural investment, infrastructure, water, fertilizers, skilled labour etc.) and thus cause food shortages and price increases
• The new incomes for farmers and rural population improve the material welfare of rural communities and this might result in a further activation of the local economy	• Biomass requires land to grow on and is therefore subject to the range of independent factors of ‘how’ and ‘by whom’ that land should be used
• Biomass-energy systems can increase economic development without contributing to the greenhouse effect since biomass is not a net emitter of CO_2 to the atmosphere when it is produced and used sustainably	• Because of the multitude of organic residues and biomass species, and the many different processing combinations that yield solid, liquid, and gaseous fuels, and heat, steam, and electric power, the selection of the best conversion technologies and feedstocks for specific applications is extremely important
• Biomass utilisation for energy production is an organised and predictable trade	• Many biomass plants, especially the decentralised ones, face grid connection difficulties
• The conversion of agricultural and forestry residues, and municipal solid waste for energy production is an effective use of waste products that also reduces the significant problem of waste disposal, particularly in municipal areas	• Biomass technologies are just starting to be supported by legislation, so the lack of legislative framework and international and national energy policies to foster large volumes of biomass and biofuels is an important barrier

6.2 The Model

6.2.1 Aims and Objectives of the Model

The drive to create a more sustainable world has required governments, businesses and individuals to examine the environmental and social impacts of current and proposed activities and to balance these impacts against goals such as economic growth, low inflation and full employment.

The objective of the technique developed here is to provide a tool for the analysis of the social, economic (economic and employment) and environmental impacts of the deployment of a bioenergy project in the regional economy. It is a preliminary analysis tool that can be used by local authorities and investors to investigate the impact of a biomass plant.

This model should be used for perennial crops and agricultural or forestry residues. The user must supply information about the project, the plant itself, the type of biomass used and some regional data in order to get information such as the Net Present Value and the Payback Period of the project, the jobs (direct, indirect and induced) created in the region, the increase in the income because of the increased demand for goods and services supplying the whole bioenergy chain.

The approach used in the model is a demand-side approach that covers only the direct, indirect and induced employment and income effects that are linked to the project. In order to measure these effects, we are using multipliers taken from the Forestry Commission's study on Scottish Forestry, "Scottish Forestry: An Input-Output Analysis", the Scottish Forestry Multiplier Analysis (May 1999) and the Scottish Executive's "Scottish Economic Statistics 2000". The multiplier effects associated with forestry are region-specific and vary significantly in accordance with the structure of the regional economy. Therefore it is important to supply accurate and regional-representative numbers.

The model cannot be used to answer questions as to what the effect on the overall macroeconomic level of employment and income.

The user has to bear in mind that:

1. The results depend entirely on the data provided and therefore every effort must be made to supply accurate and realistic data.

2. The final employment and income effects should only be treated as estimates and not as absolute numbers.

6.2.2 Structure of the Model

The model is based on four linked spreadsheets, s1, s2, s3 and s4.

The first worksheet, ‘s1’, is the “scene setter”. It contains information about the plant; location, energy information, different technologies, prices and subsidies received. The user has to input information on this worksheet. It is underlined that the information given on this sheet has to be directly relevant to the project and as accurate as possible, so that the results reflect the truth and avoid errors. When the default values are used, the user has to bear in mind that the results will be affected and the employment outputs over or under estimated. Therefore, every effort has to be made to provide complete and precise data for the project being modelled.

The user inputs data on the cells with light blue colour. All financial data is in UK sterling (£).

The second worksheet, ‘s2’, contains the technical information about the plant, such as the fuel required, the energy equipment and development costs and the financial parameters used in the financial analysis (inflation rates, interest rates). The user has to input data on this worksheet as well.

The model calculates the odt (4) of biomass necessary to operate the plant, and gives the number of tonnes. The management costs of the feedstock (planting, harvesting, storage, transportation) are not calculated separately. However, in the final analysis, these procedures are taken into account for their employment and income effects.

The third worksheet, ‘s3’, contains the results of the financial and social analysis. It provides analytical Annual Cash Flow and Cumulative Cash Flow tables, the Cumulative Cash Flow over Time graph, the Net Present Value and the Internal Rate of Return of the project and the impacts on employment and income from the initial investment in biomass production and the bioenergy plant. The user does not need to input any data on this worksheet. The financial assessment reads the data from sheets ‘s1’ and ‘s2’ and makes the calculations.

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[4] Oven-dry weight: The basic unit for quantifying woodfuel is the "oven dry tonne" (odt). The oven dry weight (measured in odt) of a load of wood fuel is the weight of all of the actual, burnable wood in the load: i.e. not including the water in the wood.
http://www.britishbiogen.co.uk/bioenergy/heating/woodasafuel.htm

The last worksheet, ‘s4’, provides information and data on the benefits of the biomass plant on the environment. It gives calculated values of the fossil fuel and emissions savings. The model uses the plant output (electricity and heat) and default data of energy contents and emissions, and calculates the environmental gains.

The model uses cash flow analysis and investment techniques to determine the profitability and financial viability of the plant. This is established by using investment indicators such as the net present value (NPV) and the internal rate of return (IRR).

Additionally, the technique quantifies the magnitude of the employment and income effects on the economy. By using multiplier analysis, it shows the impact on the number of FTE (full time equivalent) jobs in the economy associated with the new level of economic activity, as well as the estimated impact on the level of gross income in the economy.

The multipliers used here are all Type II multipliers, which sum together direct, indirect and induced effects. These multipliers are demand-driven multipliers that measure the so-called backward linkage effects in the economy.

Figure 6 illustrates the connection between the four spreadsheets.

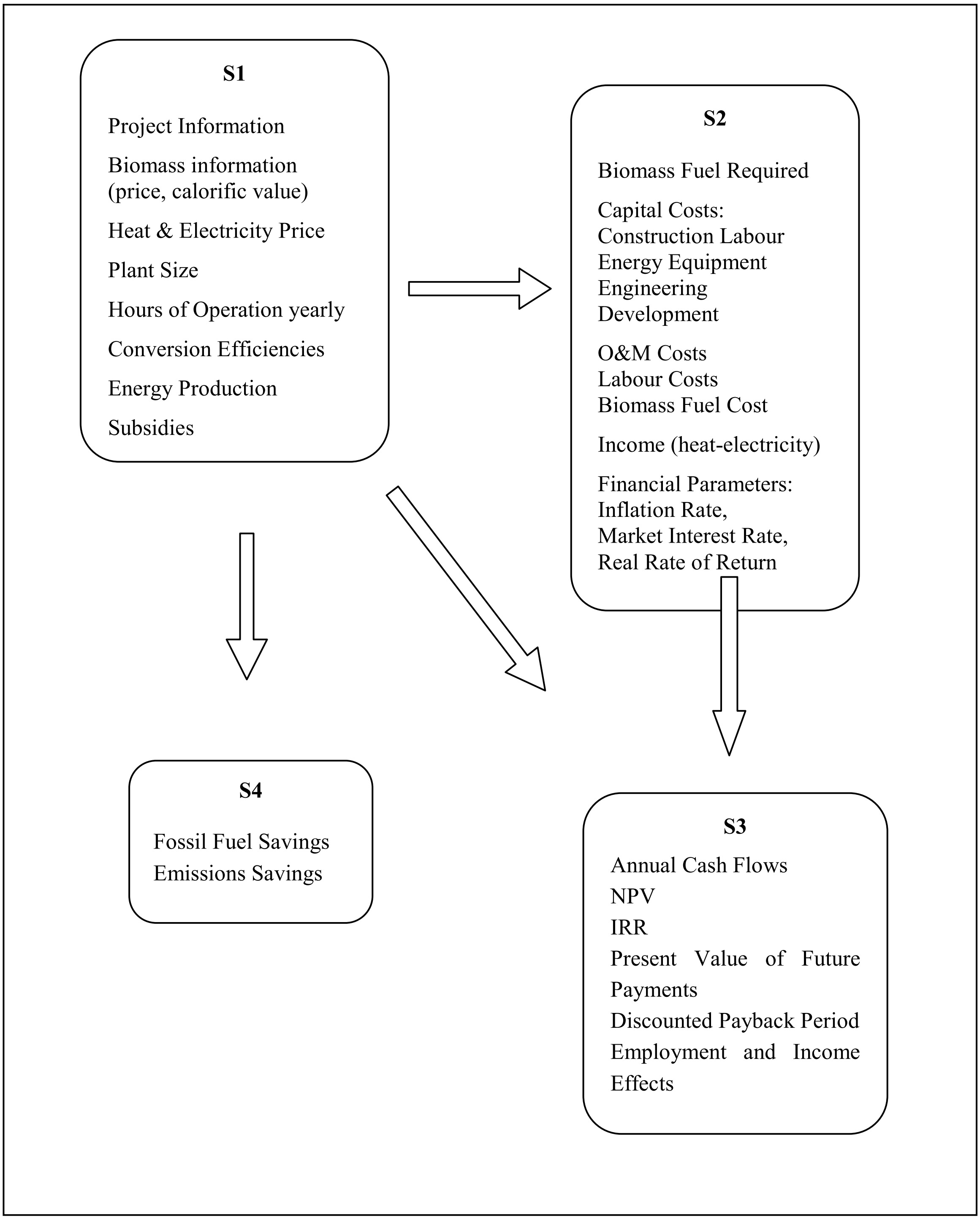

Figure 6

Figure 7 describes the interconnections between the various elements of the three spreadsheets and between the spreadsheets themselves.

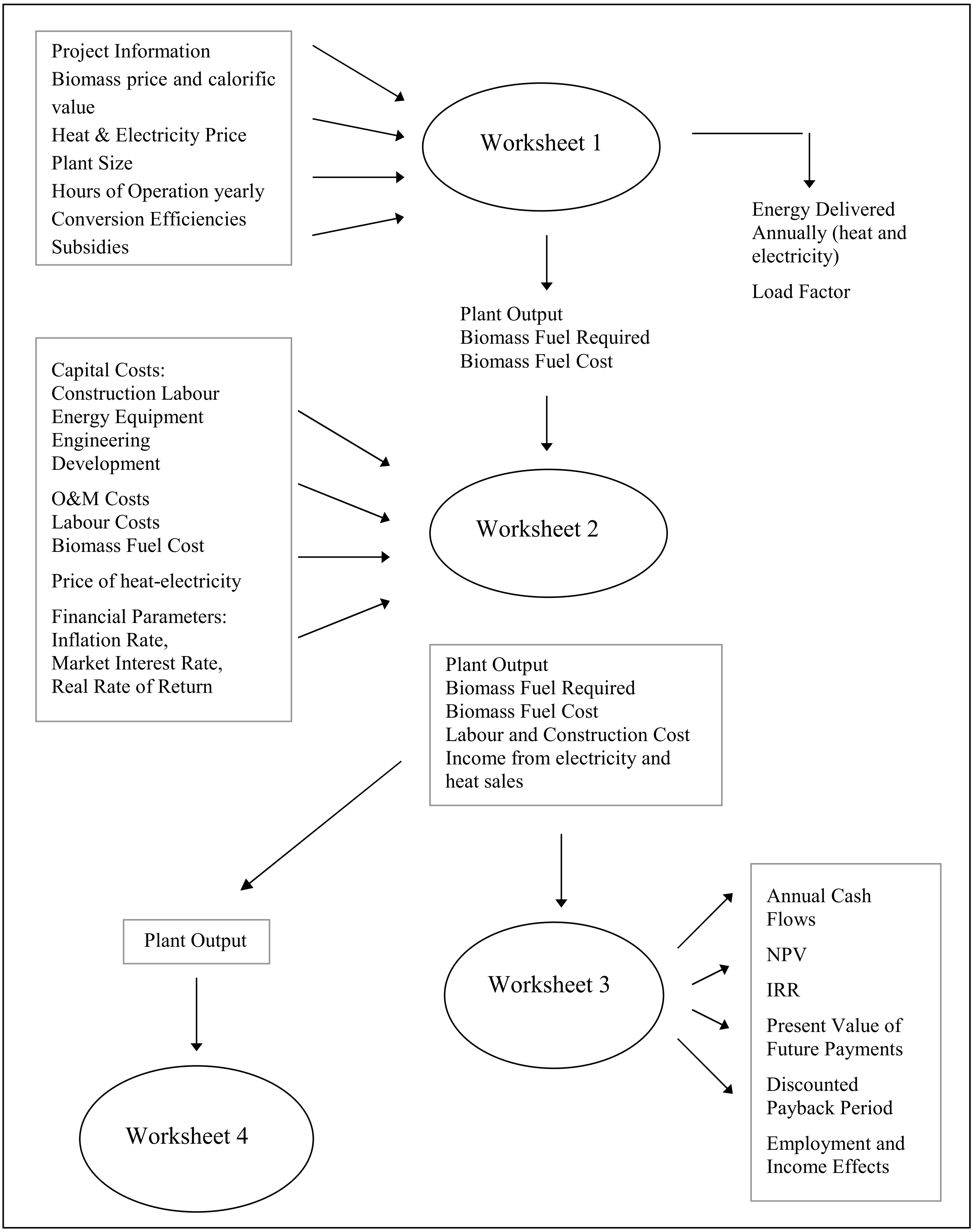

Figure 7

6.2.3 Limitations

The model exhibits some limitations.

1. The model does not capture displacement effects, which can be important in the agricultural sector and the energy market. However, the impact of a small bio-energy development on energy prices and product markets will be marginal in most instances.
2. The model should be used for perennial crops and agricultural or forestry residues.
3. The model results are project and region specific. Therefore, it is important to supply accurate and regional representative numbers.
4. The model cannot be used to answer questions as to what the effect on the overall macroeconomic level of employment and income.

6.2.4 Analysis of the Model

The following analysis covers with detail the various sections and components of the model and describes how they are connected with each other, giving the formulas used and their sources.

Worksheet 1: Energy Information

This worksheet contains all the information about the plant, the biomass fuel used, the prices and subsidies received.

Project Information

The user defines the project name and the location for reference purposes.

Biomass Type

The user enters the biomass type (woodchips, forestry/farm residues, short rotation coppice).

Biomass Moisture Content

Typical values for moisture contents range from 25% to 50%. Lower moisture contents allow more usable energy to be extracted from the biomass fuel.

When there is information of moisture content on a dry basis, the following conversion should be applied:

$$moisture\_content\_wet\_basis = \frac{moisture\_content\_dry\_basis}{1 + 0.01 \times moisture\_content\_dry\_basis}$$

Biomass Calorific Value

The calorific value of the biomass is the energy content of one tonne of the biomass. This value has to be entered as MWh/tonne. Calorific values for biomass and waste can be found in PHYLLIS, a database containing information on the composition of biomass and waste (5). The conversion from kJ/kg to MWh/tonne can be done using the equation

$$1\, {}^{kJ}\!/_{kg} = 2.7778 \times 10^{-4}\, {}^{MWh}\!/_{tonne}$$

Size of Plant

The user enters the power output - electricity and heat - in MW_e and MW_{th}.

Systems Used

The user defines if there is a base-load and peak-load system, if there is one gasifier or two smaller ones etc. For example, in the heating system, the user might want to install instead of one boiler, two or three smaller ones as this option gives the opportunity of operating just one boiler more efficiently during lower load periods and also provides time to do annual maintenance.

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[5] URL: http://www.ecn.nl/phyllis/

Conversion Technology

The user defines which technology is used (e.g. updraft gasification, combustion).

Area of Biomass Harvested per Year

The user enters the area harvested per year to provide the necessary biomass for the plant.

Biomass Price

The user enters the price of the biomass to the producer (farmer or local business) in £/odt. This price tells the user how much the supplier is charging per unit of actual solid wood being supplied and therefore allows comparisons with the prices of other woodfuels and fossil fuels. The supplier will obviously charge more for more processed and dried woodfuels than for raw, wet woodfuels.

It is assumed that the producer is responsible for the production, storage and transportation of the fuel.

Heat and Electricity Price

The user enters the market prices for the heat and electricity. The values are in £/MWh.

Hours of Operation per Year

The user enters the hours of operation of the plant per year.

Energy Delivered

The energy delivered per year is calculated by multiplying the plant size with the hours of operation per year and the conversion efficiencies.

energy production = plant size x hours of operation per year x conversion efficiency

Load Factor

The average system load factor is defined as follows:

Load Factor = hours of operation per year ⁄ 8760 hours

Conversion Efficiencies

The user enters the conversion efficiencies (to power and to heat and power).

Subsidies

The user enters the subsidies received for the biomass fuel and the biomass plant. These are defined as pounds per hectare or pounds per hectare per year for the biomass fuel and as pounds or pounds per MWh or pounds per year for the biomass plant.

There are many programs supported by the EU with the aim of augmenting the use of renewable energy resources. The Joule III program and the CEET-program of THERMIE could support biomass projects with the investment costs. Other EU support programs that are appropriate for the biomass plants are the AIR and the ATHENER programs.

Worksheet 2: Bioenergy Plant

This worksheet contains all the information about the capital costs of the plant (planning, construction, energy equipment purchase and installation, operation and maintenance).

1. Capital

Plant output

The model inserts the values of the Size of Plant from Worksheet 1.

Biomass Fuel Required

The model calculates the annual biomass fuel requirement of the plant using the annual energy production of the system, the biomass calorific value and the conversion efficiency.

$$annual\_fuel\_consumption = \frac{annual\_energy\_delivered}{calorific\_value \times power\_conversion\_efficiency}$$

Plant Site Cost

The user enters the value of the land purchased to build the plant.

Labour Costs

These include the salaries of the construction engineers and workers. The user has to input the number of labourers and engineers employed for the construction of the plant, their monthly payments and the number of months that are being employed. Using these inputs, the model calculates the labour costs.

Energy Equipment Cost

The user enters the cost of the Biomass System, the Transfer Stations and Distribution Pipelines (if any are installed).

Development Cost

The user enters the cost of the biomass resource assessments, the site investigations, the contracts, the project management, the Environmental Audits and the various legal costs.

Engineering Cost

The user enters the construction supervision costs and the site/building/energy system design costs.

Other Costs

The user enters any other costs that that are incurred and are not included in the above categories.

Construction Time

The user enters the estimated time needed to complete the construction of the plant.

2. Operating and Maintenance

The operation of a plant creates a number of annual costs. These include operation and maintenance costs, labour costs, biomass fuel costs and various payments (like insurance).

Plant Operating Life

The user enters the project life. The model uses the project life to perform the financial analysis (internal rate of return, present values etc).

Biomass Fuel Cost

The annual cost of the delivered fuel to the plant is calculated by multiplying the price of the fuel with the annual fuel consumption.

biomass cost = biomass price x annual fuel consumption

Labour Costs

These include the plant operator and engineer costs. As in the case of the construction labour costs, the user has to input the persons employed at the plant, the time for which they are working at the site and their salaries. The model, then calculates the yearly M&O labour costs.

Annual Maintenance

These costs include the annual maintenance costs (repairing or replacing wear items) and administrative costs.

A study made by the International Scientific Council for Island Development (INSULA) for the Implementation of Large Scale Deployment of Renewable Energy Sources in Crete-Greece [19] assumes that the annual maintenance and operation costs for a biomass plant are in the range of £130,000 per MW of installed capacity. Therefore, if the user does not hold any specific-site data, this assumption can be used. The model calculates the annual M&O costs by multiplying the electrical capacity of the plant with the above-assumed cost.

Fuel for Back-up System

The user enters the annual cost of the fuel supplied to the back-up system. This may be diesel or oil or gas and is expressed in pounds (£).

3. Financial

Price of Electricity and Heat

The program enters automatically the value given at the Energy Information Worksheet for the price of the electricity and heat sold to the customers.

Financial Parameters

Inflation Rate

In general, the prices of services and goods increase with time (inflation). Decrease in the costs may also occur (deflation), but it is a seldom exception. The increase in prices per unit of time is called inflation rate. The inflation rate is a measure of the average change in prices across the economy over a specified period, most commonly 12 months - the annual rate of inflation. Inflation rates can be different for different goods.

A reasonable estimate for long-term inflation is around 4%, but inflation has historically varied tremendously by country and time period. There are several databases that provide historical data on inflation rates (6).

The model has a default value for inflation 3.0%, but the user can input any other value that he/she believes is more appropriate.

Market Interest Rate

The term interest is used to designate a rental amount charged by financial institutions for the use of money. The market interest rate is received as a result of investing funds, either by loaning it or by using it in the purchase and operation of a facility. Interest received in this connection is gain or profit.

The model uses a default value for market interest rate of 10%. The user can change this value with any other more appropriate or site-specific.

Real Rate of Return or Discount Rate

A value of money X today, can be discounted in T year's time at a rate of r_o% and its value is reduced to

$$X' = \frac{X}{(1 + r_o)^T}$$

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[6] Look at References no 29, 30, 31.

The method of evaluating an investment by estimating future cash flows and by taking into consideration the time value of money is called *Discounted Cash Flow Analysis (*DCF).

A term usually used in the financial evaluation of a project is the Hurdle Rate. This is the required rate of return in a discounted cash flow analysis, above which an investment makes sense and below which it does not.

Typical values for discount rates in EU countries range from 5% to 7%. In countries of the Western Europe, it could even be as low as 3%. When the investors have a high demand for profitability, they might want to use a higher, say, 7%.

The model calculates the discount rate from the market interest rate and the inflation rate, by extracting the one from the other.

Worksheet 3: Financial Summary

Net Present Value

The net present value (NPV) is the present worth of the total profit of an investment. It is expressed as the difference between the present worth of all expenses and the present worth of all revenues and is a valuable indicator because it recognises the time value of money.

A general expression of the NPV is

$$NPV = \sum_{t=0}^{N} [F_t / (1 + d_t)^t]$$

where F_t is the net cash flow (revenue + savings - expenses) in year t and d_t the discount rate during the period t. In preliminary assessments, F_t is often considered constant, $F_t = F$. If the interest rate is considered constant, then

$$NPV = \sum_{t=0}^{N} [F_t / (1 + d)^t]$$

Since d is used to discount future amounts to their present worth, it is called market discount rate and its choice is a matter of great importance for organisations (much time and money is spent into the choice of a discount rate).

F_0 represents the present worth of the investment (t=0) and it is negative.

There are three characteristic situations when calculating the NPV:

- Positive NPV, that indicates that an investment is economically viable
- Negative NPV, that indicates that the investment is not economically viable
- NPV equal to zero, that indicates that the investment is potentially viable and has a return on the investment equal to the internal rate of return (see bellow)

Internal Rate of Return

Internal rate of return (IRR) of an investment is the true interest yield provided by the project over its life. It is defined as the interest rate that equates the present value of the future receipts of a project to the initial cost (in other words, that causes the present worth of a series of expenses to be equal to the present worth of a series of revenues). Alternatively, it is defined as the interest rate that causes the net present value (NPV) of a project to be equal to zero.

$$NPV = \sum_{t=0}^{N} [F_t / (1 + d^*)^t] = 0$$

and hence IRR = d*

The IRR is examined to determine if it exceeds a minimally acceptable return, often called the Hurdle Rate. The Hurdle Rate is the required rate of return in a discounted cash flow analysis, above which an investment makes sense and below which it does not. It is also called Required Rate of Return. An organisation may have more than one Hurdle rates, depending on the perceived risk of the projects.

The advantage of IRR is that its results allow projects of different sizes to be easily compared, unlike NPV.

Present Value

The value of money changes with time. The Present Worth or Present Value (PV) of a future amount F is the value in today's money (e.g. UK pounds) assigned to this amount F, based on some estimate rate-of-return over the long-term.

The Present Value of a cash stream gives the cost in today's pounds of money that is been paid over time. Basically the money an organisation pays in 10 years is worth less than that paid tomorrow.

The formula for the present value is

$$P = \frac{F}{\prod_{t=1}^{N}(1+d_t)}$$

where P is the present value of the future amount F and d_t the discount rate.

If the interest rate is considered constant throughout all time periods, then the equation is transformed in

$$P = \frac{F}{(1+d)^N}$$

The model calculates the present value of annual costs, which is the value of all future cash flows incurred to operate, maintain and finance the project, over its lifetime, in today's pounds.

Payback Period

It is defined as the length of time required to recover the investment cost and the desirable interest from the net cash flow produced by the investment. The payback period is not a measure of how profitable a project is in comparison to another and therefore should not be used as a primary indicator for the evaluation of a project. It can be used, though, as a secondary indicator to evaluate the level of risk of a project.

If the net cash flow (revenue + savings - expenses) in year t, F_t, can be considered constant, $F_t = F$, then the payback period can be calculated from the expression

$$PB = \frac{-\ln(1 + \frac{F_o}{F} \times d)}{\ln(1 + d)}$$

The above expression gives the Discounted Payback Period, which takes into consideration the time value of money.

An investment is considered economically viable with the payback period as a criterion, if its payback period satisfies the investor's expectations. In general, the more quickly the cost of an investment can be recovered, the more desirable is the investment.

Multipliers and Multiplier Effects

As it has been mentioned before, the difference between the multiplier and multiplier effect is that the multiplier is a ratio and not an absolute number, while the multiplier effect refers to the number of jobs (or the income) created by the basic jobs (or income).

The default values used in the model are income and employment multipliers and effects from the Scottish Economic Statistics 2000 [20] and the Forestry Commission's 'Scottish Forestry - Input-Output Analysis' [21].

The production cycle of the forests has been split in planting, maintenance and harvesting. In this study only the maintenance and harvesting stages are taken into consideration, since it is assumed that forestry residues are being used in the biomass plant. The results of the Forestry Commission's Analysis indicate that different woodland types generate very different levels of income and employment effects in the Scottish economy per unit change in demand. Therefore, in the model, the *all-Scottish forestry* maintenance and harvesting multipliers and multiplier effects are used.

The Production and Distribution of Electricity and the Construction employment and income multipliers are taken from the 1999 Input-Output Tables and Multipliers for Scotland [22].

Worksheet 4: Emissions and Fossil Fuel Savings

As we've mentioned before, biomass is not a net emitter of CO_2 to the atmosphere when it is produced and used sustainably. Through the use of biomass for the production of electricity and/or heat, we can help mitigate the climate deterioration and preserve the environment.

In this final worksheet, the user can get an impression on the amount of fossil fuels and emissions that can be saved when using biomass to produce electricity and heat.

On the Emissions-savings table, the model provides a range of CO_2, SO_2 and NO_x amounts saved in kg per year. The calculations have been made according to the emissions released from a fossil fuel plant when it produces the same amount of energy with the biomass plant (7). Taking into account the different efficiencies for different plants and the amount of pollution released from the combustion process, we calculate:

For the production of 1MWh

- the minimum amount of CO_2 released is 453.6 kg/year and the maximum 1,102 kg/year
- the minimum amount of SO_2 released is 1.361 kg/year and the maximum 9.072 kg/year
- the minimum amount of NO_x released is 0.907 kg/year and the maximum 4.536 kg/year

On the Fossil Fuel savings table, the model provides the savings of natural gas, oil, diesel and coal in litres per year or tonnes per year. The savings are estimated both for electricity production only, and for electricity and heat production. The calculations have been made according to the energy content (heating value) of the different fossil fuels. In these calculations, the model does not take into account the different conversion efficiencies of different plants. Therefore, in reality the amounts of fossil fuels saved are greater than the ones calculated here. However, the figures here provide a good measure for comparison.

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[7] Figures taken from the US Natural Resources Defence Council's website http://www.nrdc.org/air/energy/utilprof/compare.asp

The data used here are:

Energy Content of Natural Gas: 0.00962 kWh/lt.
Energy Content of Oil: 12,240 kWh/tonne
Energy Content of Diesel: 10 kWh/lt.
Energy Content of Coal: 7,506 kWh/tonne

6.2.5 Operation of the Technique

A practical implementation of the model follows. The user needs to have some data about the construction and operation of the bio-energy plant, the biomass feedstock and some economic data about the region.

The data used here are for a Scottish case study example. The values used are typical market values (e.g. prices for electricity and heat, engineering salaries, equipment). The multipliers are specific for Scotland.

In this example, the biomass power station planned is a CHP plant using perennial crops or forestry residues. The plant's operating life is 25 years. The calorific value of the biomass fuel is assumed to be 5.29 MWh/tonne and its price 28 p/odt. Taking this value and combining it with the power output of the plant, the hours of operation per year and the conversion efficiencies, it is possible to calculate the yearly amount of biomass fuel required, and therefore its cost.

The engineering, construction, operating and maintenance costs are entered as typical, average values, combined and compared with real life values.

The inflation rate and the real rate of return are the default values that the model uses (3% and 7% respectively).

The analysis of the data is presented on the worksheet 's3'. Here we conclude whether the plant is financially feasible and what are its impacts on the local economy.

The specific plant, proves to be economically viable:

- It has a payback period of 6.12 years, which makes the plant economically desirable.
- The value of the internal rate of return is quite high (20.5%), which proves that the project is acceptable.
- The net present value of the project is positive (£1,030,518).

The results of the analysis are presented in **Table 4**.

Capital Investment		£885,500
NPV		£1,030,518
IRR		20.5%
Present Value of Future Payments		-£10,390,671
Discounted Payback Period		6.12

Table 4

The multipliers used are shown in **Table 5**.

	Employment Multiplier	**Income Multiplier**	**Employment Effect per £1m increase in demand (FTE)**	**Income Effect per £1m increase in demand (£)**
All Scottish forestry harvesting	1.766	2.966	34.304	0.438
All Scottish forestry Planting/Maintaining	1.805	1.744	29.061	0.564
Production and Distribution of Electricity	5.438	3.341		
Construction	1.868	1.971		

Table 5

The employment effects of the project are quite impressive:

- 24 jobs are directly created during the construction and operation of the plant
- 38.68 indirect and induced jobs are created during the construction and operation of the plant
- in total, 66 jobs are created through the construction, operation, maintenance of the plant and the biomass production

The employment created is presented in **Table 6**.

Construction of the plant	
Direct jobs created	19
Direct, indirect and induced jobs created	35.49
Indirect and induced increase in full-time equivalent jobs	16.49
Operation and Maintenance of the plant	
Direct jobs created	5
Direct, indirect and induced jobs created	27.19
Indirect and induced increase in full-time equivalent jobs	22.19
Biomass Production	
Total (direct and indirect and induced) increase in jobs created in biomass planting and maintaining	1.85
Total (direct and indirect and induced) increase in jobs created in biomass harvesting	2.18
Total increase in Direct, Indirect and Induced jobs	66.71

Table 6

The income effect of the project is:

- a total (direct, indirect and induced) increase in the local income of £995,322 is created

Detailed analysis of the income effects is given in **Table 7**.

Construction of plant	
Direct increase in household income (£)	295,500
Direct, indirect and induced increase in household income (£)	582,431
Indirect and induced increase in household income (£)	286,931
Operation and Maintenance of the plant	
Direct increase in income (£)	104,000
Direct, indirect and induced income effect (£)	347,464
Indirect and induced income effect (£)	243,464
Biomass Production	
Total increase in income (£)	1.85
Total increase in income (£)	35,823
Total increase in income (£)	965,719

Table 7

The effects on the environment from the saving on fossil fuels and emissions are:

- around 6,000 tonnes/year of CO_2
- 2,000 tonnes/year of coal or 1,500 m^3/year diesel

Details on the savings on fossil fuels and emissions are presented in **Table 8**.

Savings on Fossil Fuels		
	from the production of electricity only	from the production of electricity and heat
Natural Gas (lt/year)	74,844,075	155,925,156
Oil (tonnes/year)	588	1,225
Diesel (lt/year)	720,000	1,500,000
Coal (tonnes/year)	959	1,998
Savings on Emissions		
	from the production of electricity	
	minimum savings	maximum savings
CO2 (kg/year)	3,265,920	7,934,400
SO2 (kg/year)	9,799	65,318
Nox (kg/year)	6,530	32,659

Table 8

6.2.6 Sensitivity Analysis

A sensitivity analysis has to be implemented in order to check the reliability of the model. Mathematical models must be sensitive to large changes in parameter values; otherwise, a wide range of values will produce largely the same behavior. Therefore, it will not be possible to confirm that the correct values have been used and the structure of the model will be questionable. A model must also be robust with respect to small uncertainties in parameter values. Otherwise, small errors in the parameter values will produce larger additional motions, making the model not testable and its predictions unreliable.

Two sets of Sensitivity Analyses have been carried out here – the first in respect with the plant operating life and the other in respect with the biomass price.

In both cases we observe that the model behaves normally with the changes in the parameters.

By increasing the number of the plant's operating years, the values of the Net Present Value and the Internal Rate of Return are automatically increased. Therefore, the analysis agrees with the fact that the plant becomes more economically viable the longer it operates (as it continues to gain income for a longer period).

By decreasing the price of the biomass fuel, the plant becomes again more economically feasible. The increase in the Internal Rate of Return is more impressive here, making thus the price of biomass a more important parameter in the financial analysis of the project.

The figures and results of both Sensitivity Analyses are presented below.

1. Changes in the Operational Lifetime of the Plant

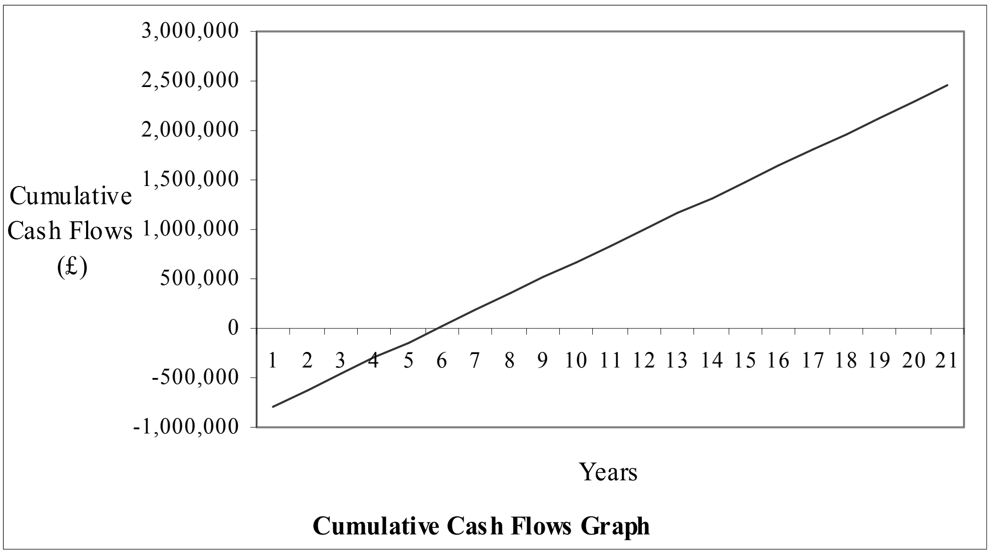

Figure 8 Operational Life of the plant - 20 years

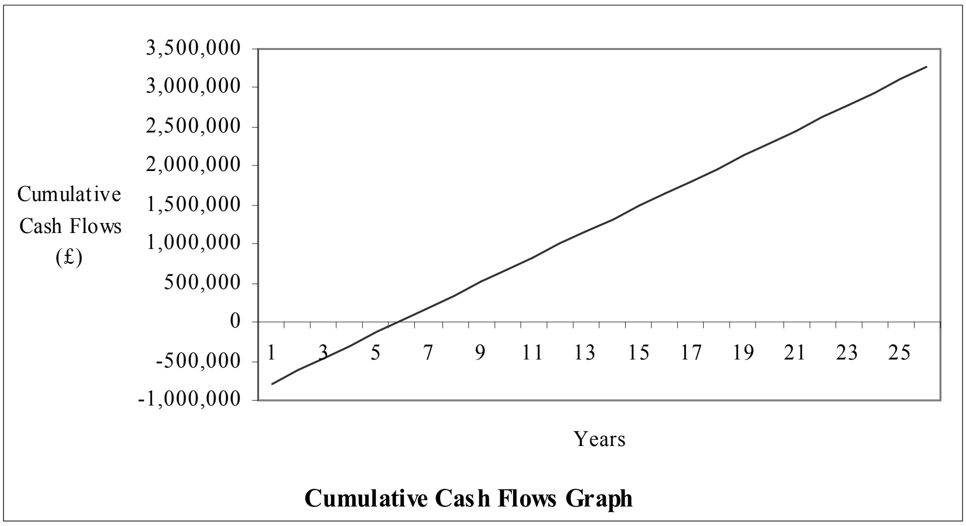

Figure 9 Operational Life of the plant – 25 years

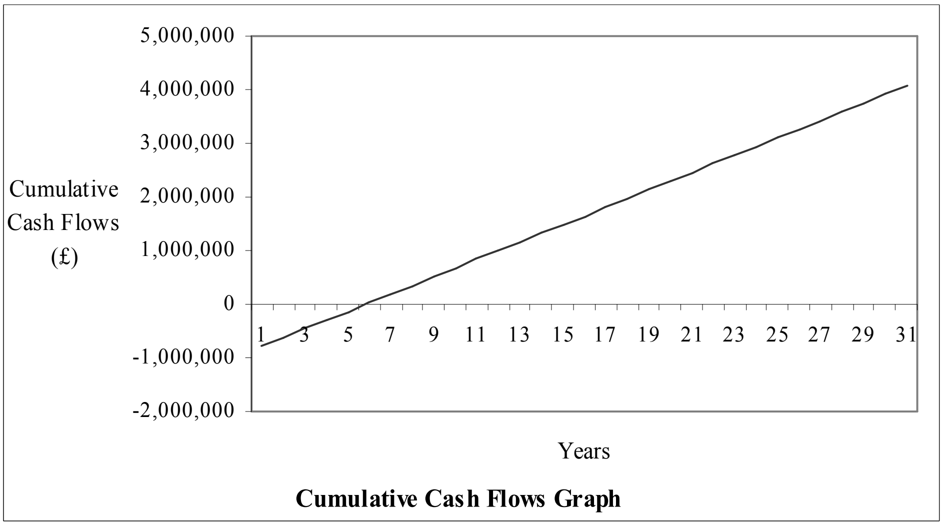

Figure 10 Operational Life of the plant – 30 years

Table 9 presents the financial details for each case of the sensitivity analysis.

Plant Operating Life (years)	20	25	30
Capital Investment	£885,500	£885,500	£885,500
NPV	£870,202	£1,030,518	£1,144,821
IRR	20.1%	20.5%	20.6%
Present Value of Future Payments	-£8,392,465	-£10,390,671	-£12,388,877
Discounted Payback Period	6.12	6.12	6.12

Table 9

2. Changes in the Price of Biomass Fuel

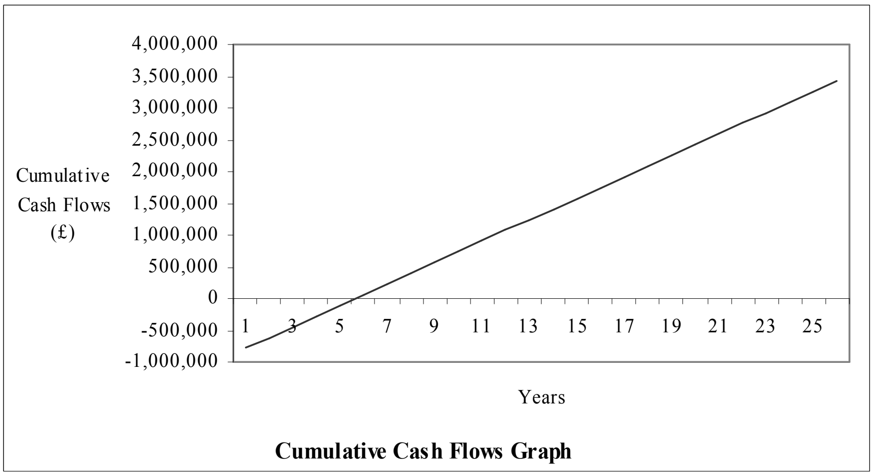

Figure 11 Cost of Biomass Fuel – 35 p/odt

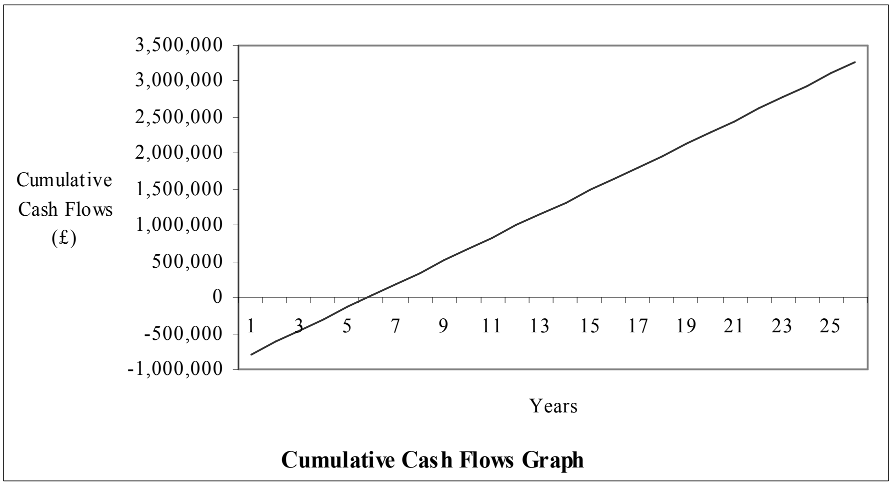

Figure 12 Price of Biomass Fuel – 28 p/odt

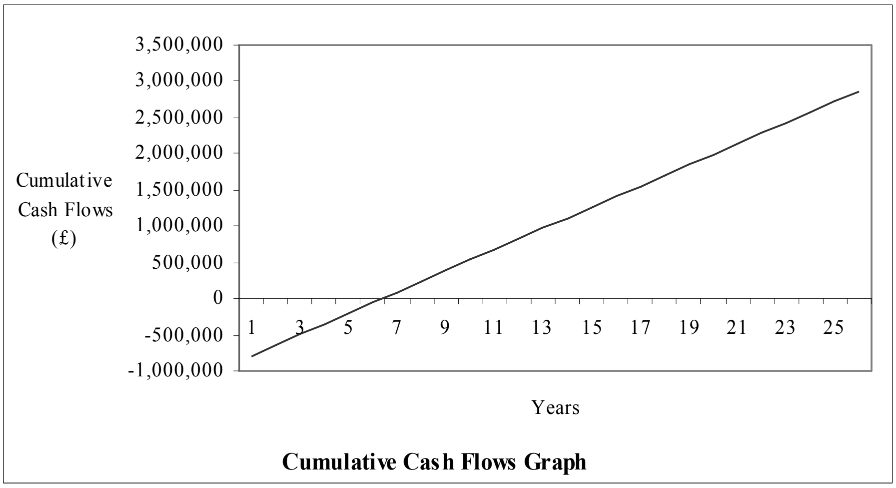

Figure 13 Price of Biomass Fuel – 25 p/odt

Details of the financial parameters on each case are given in **Table 10**.

Biomass Price (£/odt)	25	28	35
Capital Investment	£885,500	£885,500	£885,500
NPV	£1,104,636	£1,030,518	£857,577
IRR	21.3%	20.5%	18.3%
Present Value of Future Payments	-£10,225,309	-£10,390,671	-£10,776,516
Discounted Payback Period	5.82	6.12	6.97

Table 10

6.2.7 Results

The model can be used to assess the economic and employment effects of biomass projects in a rural area. The results should be viewed and interpreted as possible effects and estimates, rather than exact and definite answers. As mentioned before, the model relies on the quality of the data provided by the user, which can be estimates in the case that regional data are not available. Therefore, it is important to try and provide as accurate and representative information as possible on the details of the plant as well as the local availability of goods and services.

It should be stressed that the results of the analysis should be considered more optimistic than they would be in reality. This is due to the fact that the model does not take into consideration the displacement effects of the transfer of the electricity (and heat) production from traditional fossil fuel or natural gas generation to biomass generation. Biomass energy production displaces some other productive economic activity, and has therefore negative economic and employment impacts in some other area. These negative effects don't offset the positive effects from the biomass project, but have to be taken into account when trying to interpret realistically the results of the model.

Furthermore, when interpreting the results of the model, the user has to use his/her common sense. For example, if for a 1MW plant the model forecasts that 500 jobs will be created in the local economy, then it is apparent that some mistake has been made when entering the data. The user then has to go through the procedure of checking the data and correcting the error.

The user has to bear in mind that economies of scale affect the labour requirements of power plants. It is therefore assumed that the employment and income effects are not proportionate to the plant size and the user should not expect any such rise.

After having considered all the above limitations and restrictions, the user can interpret the results of the model and decide on the viability of the project.

Chapter 7 CONCLUSIONS AND DISCUSSION

7.1 Discussion

Biomass is a versatile and important fuel. The potential for increased exploitation of biomass resources is very large, with significant opportunities associated with the development and commercialisation of biomass conversion technologies, the development of energy crops and their management, and the implementation of biomass energy projects. Biomass technologies are undergoing continuous development both for small and large-scale applications.

The methodology used in this thesis to identify the potential and limitations of biomass deployment for the production of modern energy forms – electricity, combined heat and power, gaseous and liquid fuels – proved that biomass has a significant potential to contribute.

A detailed analysis on the different technologies used, the social-economic-environmental impacts of biomass use and its relationship and interactions with other energy markets, has demonstrated its considerable expansion over the last decade as well as the barriers that have to be yet overcome.

The development and operation of the model confirmed that bioenergy projects are economically viable, even without taking into consideration the benefits of emission reduction on the people and the environment.

7.2 Limitations

Biomass use for the production of energy is not yet as economic as the use of fossil fuels or nuclear power. Most research and development issues are concerned with how to deliver energy at an acceptable cost and how to manage the high industry growth rate needed to meet the required (by governments, EU etc) deployment.

Planning can be another limitation to the deployment, if an appropriate site is not chosen. The security of fuel supply and the low cost of fuel transport are very important when planning a biomass project. There are examples of projects that reached the point of failure because of the lack of appreciation of these factors.

Another factor that has to be taken into serious consideration is the interpretation of the economic and employment effects of a plant within the context of the regional economy. If a large biomass plant with capital cost of 3 million pounds creates only 5 fte (8) jobs but at the same time prevents the depopulation of the region, this can be valued more than if the same effect had taken place in an area with fast urban growth. It is important to consider not just the amount but also the value of employment creation and market regeneration in rural areas.

It is not yet completely possible to evaluate and quantify in economic terms the full range of effects of the creation of a bioenergy plant on the environment and the people. Studies - like EXTERNE -concerned with the quantification of the emissions reduction effects on human health, the natural ecosystem and the environment are starting to be used more widely in the planning process. However, there are not yet widely commercially available models that can take into consideration all these factors and help planners and developers appraise the actual value bioenergy projects have.

The model developed here does not include such an analysis. To comprise such an investigation would require an enormous amount of information, most of which is not available for the region in question.

Time was another restriction in the more analytical and in depth study of these effects. An initial research and the provision of the background information on this subject are provided here.

It has been stressed that the data used in the model for the financial evaluation of a project have to be as accurate as possible and representative of the region. Fuel prices, equipment prices, labour costs have to be realistic in order to give exact and credible results. The multiplier values must also be precise, as they represent the social dimension of the analysis, which is as important as the financial. It is not always easy to find data that are regional or that have been broken down and divided in more detail (e.g. income and employment multipliers for biofuel planting, maintenance, harvesting and transport for different kinds of biofuels and for different regions). For example, for the case study investigated here, the multipliers used are representative for the whole of Scotland, making it difficult to take very accurate results.

In any case however, the results should be viewed and interpreted as possible effects and estimates, rather than exact and definite answers.

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[8] fte: full time equivalent

7.3 Further Work

Two were the main obstacles in the further analysis of this thesis - time and lack of ready and easy-to-find information.

The time limit for its completion was very narrow to search for and include in more detail every aspect of the energy production from biofuels. Additional analysis could have been made on the externalities of biomass – the consequences that energy production from biofuels has on society and the environment. For example, CO_2 fixation could have been included in the analysis made by the model, so that the external benefits are taken into account. The displacement effects of a biomass plant in the agricultural sector and the energy market could have also been included in the analysis. However, the only way to make sure that the results obtained from such an analysis are accurate and realistic is to conduct a detailed and thorough analysis, which is time consuming.

The lack of information was another barrier to hinder the further progress of the model analysis. Information such as employment and income multipliers are not yet site specific and therefore data representative of a region or local county are not available. Furthermore, it's not easy to find detailed information of the impacts of different life-cycle processes on the local and ecological environment. Studies on the impacts of biomass transport and their quantification are still being developed and the results are not available for more extensive and broad use. The acquisition of statistical data on employment and data from case studies was not easy and some times it was even forbidden. Further work needs to be done therefore in data gathering and analysis.

More work could have been done on the final part of the model. Worksheet 4 could have been more detailed in the analysis of the emissions savings, giving a clearer picture of the benefits on the environment. The addition of economic figures, like CO_2 fixation, makes the analysis clearer and the comparison between the different benefits more effective. It is easier for planners to have all the results in the same format, e.g. economic figures, so that they can see directly the benefits or negative aspects of a project.

To summarise all the above, the acquisition of more detailed data and their analysis so as to make them readily usable is the main focus for further work.

7.4 Conclusions

Most energy scenarios indicate biomass energy to be a key component of the global future energy mix, with significant benefits in terms of environment and development.

Engineering assessment suggests that capital costs could be significantly reduced through reproduction and economies of scale once the plants enter early commercial application. Much lower costs could be achieved in co-firing applications and gasification technologies. Improvements in technologies promise further cost reduction and increased potential and production of energy.

Many models that try to identify and quantify the effects of bioenergy generation on the surrounding economic, social and environmental climate have been (and are still being) developed, proving thus the growing interest in bioenergy. The fact that these models are not only techno-economic but examine also the direction and source of the capital flows and the employment and environmental impacts, proves the growing interest in the social and environmental implications of the human activities. These implications can now be identified and quantified in most cases and therefore taken into consideration when planning and designing policies in the energy sector.

Using the model developed above, local communities, planners, developers, RE companies and individuals interested in the renewables sector can gain an initial idea on the capital costs, the financial returns and the positive impacts on the economy and the environment a biomass project can have. Most importantly, they can combine and balance between the economic revenues they will get - the main factor that influences their decisions - and the more general benefits that their development will have in the social and ecological environment.

The drive to create a more sustainable, friendly, liveable and clean world, along with the need to integrate the social dimension of projects in the planning procedures, makes the progress in this direction imperative. The local and regional impacts of energy production from biofuels have to be appreciated along with the global benefits and there should be a steady flow of high quality scientific information to all stakeholders so that benefits are acknowledged and disadvantages identified so that they can be dealt with.

REFERENCES

[1] World Commission on Environment and Development, **Our Common Future**. Oxford, Great Britain: Oxford University Press, 1987.

[2] Charles P.Wallace. Is it a Breeze? *Time Europe,* Vol. 160 No.4, July 22, 2002.

[3] European Wind Energy Association (EWEA), "Wind Force 12; A Blueprint to achieve 12% of the World's Electricity from Wind Power by 2020".

[4] German Federal Ministry of Economics and Labour, Energy Report, Sustainable Energy Policy to Meet the Needs of the Future, June 2002, ISSN 0342 – 9288.

[5] Barker N., Technology Status Report: Biofuels (Energy from Forestry and Agriculture), for the DTI's New and Renewable Energy Program, August 15 2001.

[6] International Environmental Agency (IEA) Bioenergy, Task 29: Socio-economic aspects of bioenergy systems, Annex 29, page 1.

[7] Hall D.O., Wood J. and House J. *Biological Systems for uptake of carbon dioxide,* International Conference on Biomass for Energy and Industry, Florence, Italy, 5-9 October 1992, p. 522-528

[8] Official Journal of the European Communities, 27/10/2001, L 283, p. 33 – 40.

[9] Bridgwater and Peacoke. Fast pyrolysis processes for biomass. *Renewable and Sustainable Energy Reviews*, No 4, 2000, p.1-73.

[10] Denman J.. IEA Biomass Energy Data: System, Methodology and Initial Results, IEA Workshop - Biomass Energy: Data, Analysis and Trends, Paris, 23-24 March 1998.

[11] Saez R.M. et al. An Assessment of the Externalities of Biomass for Electricity Production, Informes Técnicos Ciemat, No 804, Sep 1996, p. 1.

[12] Bain R., Overend R., Craig K.. Biomass-Fired Power Generation, Conference on Biomass Usage for Utility and Industrial Power, Snowbird, UT, April 29 - May 3 1996, p.1.

[13] Graham and Walsh, *Evaluating the Economic Costs, Benefits and Tradeoffs of Dedicated Biomass Energy Systems: The Importance of Scale,* Proceedings Second Biomass Conference of the Americas: Energy, Environment, Agriculture and Industry, Aug 1995

[14] Dorland C., Hoevenagel R., Jansen H.M.A., Tol R.S.J., The Dutch Coal Fuel Cycle. Institute for Environmental Studies, Amsterdam 1995.

[15] Renewable Energy Policy Project (REPP), Research Report, "*The work that goes into Renewable Energy*", November 2001, No. 13, page 4.

[16] European Communities. "The impact of renewables on employment and economic growth", ALTENER Programme of the Directorate-General for energy of the European Commission, Final Report, pages 8-10.

URL: http://www.eufores.org/Employment.htm

[17] Isard Walter, *Methods of regional analysis: an introduction to regional science / by Walter Isard: in association with David F. Bramhall [et al.],* 1960, Massachusetts: Technology Press of The Massachusetts Institute of Technology and John Wiley, page 190.

[18] Davis HC. *Regional Economic Impact Analysis and Project Evaluation*, Vancouver: University of British Columbia Press, 1990, p.37.

[19]International Scientific Council for Island Development (INSULA), Island 2010 Action Project, *Implementation Plan for the Large Scale Deployment of Renewable Energy Sources in Crete-Greece,* National Technical University of Athens (NTUA - RENES) - Crete Energy Office.

URL: http://www.insula.org/island2010/PDF/Crete.pdf

[20] A2 Output, Employment and Income Multipliers, Scotland 1996. Scottish Economic Statistics 2000, Scottish Executive.

URL: http://www.scotland.gov.uk/stats/ses2000/secs-07.asp

[21] Scottish Forestry: An Input-Output Analysis, *Programme Title: Economic Impact and Multiplier Studies*, 2000.

URL: http://www.forestry.gov.uk/website/pdf.nsf/pdf/scotmult.pdf/$FILE/scotmult.pdf

[22] 1999 Input-Output Tables and Multipliers for Scotland, Scottish Executive.

URL: http://www.scotland.gov.uk/about/FCSD/OCEA/00014713/1999_IO_Multipliers.xls

[23] United Kingdom. National statistics. *United Kingdom Input-Output Analytical Tables 1995.*

URL: http://www.statistics.gov.uk/themes/economy/Articles/National Accounts/inputoutput.asp

[24] United Kingdom. DTI-Department of Trade and Industry. *New and Renewable Energy: Prospects for the 21st Century*, March 1999.

URL: http://www.dti.gov.uk/renew/condoc/energy.pdf

[25] Sørensen B. *Renewable Energy*, 2000, Academic Press, London and New York.

[26] Twidell J., Weir T. *Renewable Energy Resources*, 1986, The University Press, Cambridge.

[27] Hirschey M., Pappas J., Whigham D. *Managerial Economics*, 1995, The Dryden Press, London, UK.

[28] DeLong Max M. *Economic Development Through Biomass System Integration: Summary Report*, Dec 1995, NREL/TP-430-20517.

[29] Vaze P. Environmental Input-Output Tables for the UK, *Economic Trends*, No 527, 1997.

[30] Bendi E. *Towards Sustainable Energy Age.* Slovakia-Foundation for Alternative Energy, 1995.

[31] U.S. Department of Energy. *Overview of Biomass Technologies*. Office of Biopower and Hydropower Technologies, Jan 2000.

URL: http://www.eren.doe.gov/power/pdfs/bio_overview.pdf

[32] Biomass Socio-Economic Multiplier Technique (BIOSEM).

URL: http://www.etsu.com/biosem/

[33] The RETScreen International Renewable Energy Project Analysis Software.

URL: http://132.156.62.20/ang/d_o_view.phd

[34] Inflation Rate database – Listing countries in alphabetical order.

URL: http://www.photius.com/wfb1999/rankings/inflation_rate_0.html

[35] Economic History Services – Inflation rate values for UK and US since 1600.

URL: http://www.eh.net/ehresources/howmuch/inflationq.php

[36] Incomes Data Services - UK inflation Forecasts and European inflation.

URL: http://www.incomesdata.co.uk/statistics/stat.htm

[37] The Australian Greenhouse Office - Energy and Transport - Renewable Energy.

URL: http://www.greenhouse.gov.au/renewable/reis/technologies

[38] U.S. Department of Energy - National Renewable Energy Laboratory.

URL: http://www.nrel.gov/clean_energy/

[39] European Commission, AGORES – A Global Overview of Renewable Energy Sources.

URL: http://www.agores.org/SECTORS

[40] Environmental Law and Policy Centre.

URL: http://www.elpc.org/energy/renewables.html

[41] Corporation for Public Access to Science and Technology

URL: http://www.cpast.org/Articles/fetch.adp?topicnum=12

APPENDIX

Survey of Models for Socio-Economic Analysis of Bioenergy Systems

1. RETScreen

The RETScreen International Renewable Energy Project Analysis Software is a renewable energy technologies project assessment tool. The software is developed by the RETScreen International Renewable Energy Decision Support Centre in Canada and is provided free-of-charge. It can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of renewable energy technologies (RETs).

The RETScreen International software is useful for both decision support and capacity building purposes. In terms of decision support, the software provides a common platform for evaluating project proposals while significantly reducing the costs (down to one-tenth the cost of conventional studies), time and errors associated with preparing preliminary feasibility studies. Regarding its capacity building benefits, the software, together with the On-line product, cost and weather databases and On-line User Manual, serves as an ideal educational and industry/market development tool.

The tool is intended to be used by technical and financial personnel from electric utilities, consulting engineering firms, financial institutions, private power developers, government and development agencies and product suppliers for a variety of purposes: preliminary feasibility studies; project lender due-diligence; market studies; policy analysis; information dissemination; training; sales of products and/or services; project development and management; product development; and R&D.

RETScreen is based on Excel workbooks. There are five key worksheets provided with each technology Workbook file.

- The “Energy Model” worksheet which is used to calculate the annual energy production of the RET project being considered.
- The second is a sub-worksheet that is specific to the particular RET (e.g. “Equipment Data” worksheet).

- The “Cost Analysis” worksheet, which is used to calculate the total initial, annual and periodic project costs.

- The Greenhouse Gas Emission Reduction Analysis (“GHG Analysis”) worksheet, which is optional and is used to estimate the greenhouse gases reduced by the proposed RET project.

- The “Financial Summary” worksheet which is used to prepare the financial analysis for the RET. Numerous financial indicators are provided to help support decisions (e.g. internal rate of return, simple pay back, net present value, etc.). The results are then presented in a simple project cash flows graph for presentation to key decision-makers.

Currently, the software can be used to evaluate eight renewable energy technologies

1. Wind energy, from larger scale wind farms to smaller scale wind-diesel hybrid system applications
2. Small hydro, from larger scale small hydro developments to smaller scale mini and micro generation applications
3. Photovoltaics, from larger scale central generation plants to smaller scale distributed generation applications
4. Solar air heating, from larger scale industrial building developments to smaller scale residential applications
5. Biomass heating, from larger scale developments for clusters of buildings to individual building applications
6. Solar water heating, from small residential systems to large scale commercial, institutional and industrial systems.
7. Passive solar heating, in low-rise residential and small commercial building applications
8. Ground-source heat pumps, for the heating and/or cooling of residential, commercial, institutional and industrial buildings

It is important to keep in mind that the RETScreen tool is a pre-feasibility analysis model and that there are limitations that it cannot overcome; for example, the tool cannot evaluate smaller scale projects where energy storage is required, the time scale for energy production is annual, rather than a more detailed time series which would consider energy production and load variation on a much shorter time scale. Therefore its output concentrates on performance and financial data.

2. BIOSEM

The BIOSEM project was started in January 1997 under the FAIR Programme. The objective was to construct a quantitative economic model capable of capturing the income and employment effects arising from the deployment of bio-energy plants in rural communities. The model is available free of charge for download from the ETSU website.

The aim of the technique is to apply a quantitative technique to bioenergy (specifically biomass-to-energy) plants to analyse and capture the socio-economic (employment and economic) impacts in the regional economy. The model uses cash flow analysis and investment techniques to determine the profitability of both fuel production and use activities.

Using a Keynesian Income Multiplier approach, the BIOSEM techniques makes predictions about the income and employment effects arising from the installation of a bio-energy plant. These are based upon the availability of the goods and services needed to service the plant, an analysis of the prevailing local economic climate, the flow of income involved with each stage of the whole bio-energy process, the labour required to service both the feedstock production and the plant, and the role of the feedstock within the agricultural sector including the impact of any possible displacement effect.

A range of biomass fuels and conversion processes can be modelled, as can the recipient markets for heat and electricity. The modelling takes place in two phases: phase 1, which is the financial assessment and phase 2, which is the socio-economic analysis.

In phase 1, investment and profit margins can be traced to determine key financial indices for both feedstock production and for the conversion plant.

In phase 2, the model captures the direct and indirect employment and income impacts, the direct displacement impacts for any agricultural activities and the induced impacts caused by the spending of wages and profits for agricultural and bioenergy plant activities.

The technique is based on five linked Excel spreadsheets, sheets A-E.

A. Sheet A is the “scene-setter” and contains all the information – regional and plant input data – upon which all the other sheets are based.

B. Sheet B calculates the financial viability of crop production and the bioenergy plant over a 20-year period. It provides both annual and cumulative cash flows and investment indicators i.e. net present values, and internal rates of return, which can confirm the viability of the project, thus allowing subsequent employment and income analysis to take place.

C. Sheet C calculates all the pecuniary leakages from the regional economy.

D. Sheet D details the displacement effect of transferring one type of crop production to bioenergy production and the impact on the primary processing of the agricultural activity displaced.

E. Sheet E calculates the final direct, indirect and induced multiplier along with the income and employment gains. The basic components of the gross effect are: the direct effect, the direct displacement effect, the indirect effect, the indirect displacement effect, the induced effect and the total net impact.

The model is useful to project developers, regional economic development officers and agencies and policy makers. It should be stressed here that the technique is not designed to give a definitive answer with regard to the number of jobs created, but rather the results should be viewed as estimates of possible income and employment creation.

3. EXTERNE

The ExternE (Externalities of Energy) project was the first complete attempt to use a consistent ‘bottom-up’ methodology to assess the external costs related with a range of different fuel cycles. The European Commission launched the project in collaboration with the U.S. Department of Energy (DoE) in 1991.

Emissions and other types of burden such as risk of accident are quantified and followed through to impact assessment and valuation. The approach thus provides a logical way of quantifying externalities.

The programme has been developed in four stages:

- The development of a methodology for the evaluation of externalities associated with fuel cycles
- The application of the methodology to a range of fuel cycles with the developamnet of an accounting framework for each fuel cycle
- The application of the accounting framework to different technologies and sites
- The development of methods or the aggregation of the results so that they are of value to policy and decision makers

The framework can be applied to a wide range of receptors, including human health, natural ecosystem, and the environment. In addition, the methodology is also being extended to address the evaluation of externalities associated with the transport and domestic sectors, and a number of non-environmental externalities such as those associated with the security of supply.

The methodology relies upon a whole fuel cycle approach to impact assessment. For example, the assessment of a bioenergy fuel cycle includes the evaluation of the impacts associated with the construction of the new plant, the harvesting, the storage, the transport of biomass, the power generation, the waste disposal and the electricity transmission.

The analysis begins with the identification of the stages of the fuel cycle under assessment. A comprehensive list of burdens and impacts is then described for each stage. Priority areas for assessment are identified. Thereafter, the impact assessment and valuation are performed using the ‘damage function’ (or ‘impact pathway’) approach. This approach assesses impacts in a logical manner, using the most appropriate models and data available. Different methods include:

- Emissions. Characterisation of the relevant technologies and the environmental burdens they impose.

- Dispersion. Calculation of increased pollutant concentrations in all affected regions (air and water courses).

- Impact. Characterisation of the population or receptor exposed to incremental pollution, identification of suitable exposure–response functions, and linkage of these to give estimated physical impacts.

- Cost. Economic valuation of these impacts.

The final stage of the impact pathway analysis is the monetary evaluation. The value is measured by the willingness to pay (WTP) for improved environmental quality or willingness to accept (WTA) environmental damage.

4. ELVIRE

The ELVIRE (Evaluation for Local Value Impacts for Renewable Energy Sources) model is an evaluation tool for development projects involving renewable energies. It has been designed by FEDARENE's working group on renewable energies within the context of the ALTENER programme, which is administered by the European Commission's Directorate General for Energy.

The model evaluates the externalities associated with renewable energy projects, by weighing up the overall impacts of a project against its initial cost. It provides answers to question like: what are the benefits of a local renewable energy project in view of the fact that energy prices are low and that conventional energies are abundant? What are the environmental benefits of such a project?

ELVIRE indicates to a public decision maker considering whether to subsidise a project, its impacts on

- Regional economic development
- Employment
- The return on public finances
- Sustainable development
- The environment

helping therefore the promotion of renewable energies, as well as the implementation of information and know-how exchange networks throughout Europe.

5. SAFIRE

The SAFIRE project, supported by the Commission of the European Communities' Directorate-General for Research and Development (DG XII) under the Joule II programme, was developed by several participants, including:

- Energy for Sustainable Development Ltd (ESD, UK)
- Institut für Energiewirtschaft und Rationelle Energieanwendung (IER, Germany)
- Institute des Aménagements Régionaux et de l'Environnement (IARE, France)
- Zentrum für Europäische Wirtschaftsforschung GmbH (ZEW, Germany)
- Fraunhofer Institut für Systemtechnik und Innovationsforschung (FISI, Germany)
- Coherence (Belgium)

SAFIRE is an engineering-economic bottom-up model for the assessment of first-order impacts of 'rational' (i.e., renewable and new non-renewable) energy technologies on a national, regional or local level against a background of different policy instruments and scenario assumptions. SAFIRE is a framework that consists of a database and a computer model that provides decision-makers with a tool to evaluate the market and impact of new energy technologies and policies. Currently, SAFIRE is being updated to take into account the calculation of baselines within the Kyoto framework.

The model includes an extensive database for 22 renewable energy technologies (RETs), eight new non-RETs and seven fuelling options for co-generation plants including fuel cells.

The calculations in the model are divided in eight stages:

1. Energy demands
2. Demand side management calculation
3. Renewable energy technical potential
4. Renewable and non-renewable energy market potential

5. District heating market potential and penetration
6. Renewable and non-centralised non-renewable market penetration
7. Centralized electricity market penetration
8. Cost benefit analysis

Seven different cost-benefit indicators are calculated by SAFIRE:

1. Pollutant emissions
2. Employment
3. Government revenues
4. Energy and import dependency
5. Value added
6. Total and local capital expenditures
7. External costs

The model has been used for a variety of applications, ranging from micro-level local planning to market assessment for companies and international agencies, from cost benefit analyses for public institutions to local, regional, national and EU policy and planning.

6. INSPIRE

The INSPIRE (Integrated Spatial Potential Initiative for Renewables in Europe) project was funded through the European Union Joule Programme, and drawing upon the expertise of several EU countries, the model has been developed into an integrated methodology for the assessment of resource availability, financial viability and environmental factors for biomass-to energy options at both regional and national levels. Whilst this was initially conceived for biomass, it has been and can be applied to other renewable energy technologies as well.

INSPIRE is a framework for linking resource mapping with the economic assessment of biomass-to energy projects. The model links different resource assessment models (developed using GIS) with various financial models, which include both project and market-driven scenarios.

The GIS models are reliant upon local agricultural data and are derived from a number of different sources (terrestrial surveys, agricultural statistics etc).

The financial models used to get potential incomes from biomass related projects are:

- RECAP. It is project-driven computer model of biomass-to-energy systems
- BIOSIM. The model converts availability to energy content and uses this to generate the resource-cost map required for linking economics with resource analysis.
- MODEST. This model uses linear programming to minimize the capital and operational costs of energy supply and demand-side management over time.

By linking the existing resource data and the financial assessments of biomass production, with the markets for the bioenergy produced in terms of electricity, CHP and heat only, the model can predict the potential resource and the possible regional income derived from the production of biomass.