UK ENERGY AND ENVIRONMENTAL POLICY FOR BIOMASS HEATING OPTIONS

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List of Abbreviations Used

BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office of Economics and Export Control, Germany)
$BEAT_2$	Biomass Environmental Assessment Tool version 2
BERR	Department for Business Enterprise and Regulatory Reform
CCE	Climate Change and Energy
CERT	Carbon Emissions Reduction Target
CESP	Community Energy Savings Programme
CHP	Combined Heat and Power
CLG	Communities and Local Government
CSR	Corporate Social Responsibility
CT	Carbon Trust
DEFRA	Department of Environment, Food and Rural Affairs
DGET	Directorate General of Energy and Transport
DECC	Department of Energy and Climate Change
DTI	Department of Trade and Industry
EA	Environment Agency
EBA	European Biomass Association
EC	European Commission
ECA	Enhanced Capital Allowance
ECS	Energy Crops Scheme
EEC	Energy Efficiency Commitment
ETF	Environmental Transformation Fund
EU ETS	European Union Emissions Trading Scheme

GHG	Green House Gas
HES	Heat and Energy Saving Strategy
HMRC	Her Majesty's Revenue and Customs
IEA	International Energy Agency
ISO	International Standards Organization
LPG	Liquefied Petroleum Gas
LCBP	Low Carbon Buildings Programme
NAP	National Allocation Plan
NFFO	Non Fossil Fuel Obligation
NPV	Net Present Value
OPSI	Office of Public Sector Information
PAYE	Pay As You Earn
RES-E	Renewable Energy Source-Electricity
RES-H	Renewable Energy Source-Heat
RHI	Renewables Heat Incentive
RO	Renewables Obligation
ROC	Renewables Obligation Certificate
SDC	Sustainable Development Commission
SEK	Swedish Kronor
SRC	Short Rotation Coppice
UDP	Unitary Development Plan
VAT	Value Added Tax

Abstract

Two very realistic scenarios of biomass based heating systems were analyzed in the light of present and planned UK energy and environmental policies especially from the aspect of the different financial support mechanisms that exist or are planned to provide incentives for biomass heat and thereby promote its expansion. The level of GHG abatement using these schemes was determined as well as the cost incurred by the support mechanisms to mitigate a tonne of CO_2 emission, using the newly released $BEAT_2$. It was found that the two scenarios had the potential to significantly reduce GHG emissions in comparison to fossil fuel fired boilers, if the biomass used is correctly sourced. It was also found that the current value of support mechanisms for a tonne of CO_2 avoided in the case of a wood-pellet based biomass boiler is much lower than the price at which it is currently traded in the EU ETS sector. A final policy review with references to a couple of other successful non-UK programs is presented. This report will be of special interest to policy analysts who wish to understand about the manner in which the UK is trying to promote biomass heating and the possible room for improvement there, pending further study.

Declaration

I, Apurba Sakti, hereby declare that no portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

(Apurba Sakti)
Date: 19th May 2009

Copyright Statement

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Last but not the least; a special word of gratitude to the reader for that is where this work shall derive its meaning.

Chapter 1

Introduction and Scope of Research

1.1 Introduction

Sustainably produced biomass is an alternative to fossil fuels which can substantially reduce associated greenhouse gas emissions. This benefit arises primarily when the carbon in the biomass has been relatively recently sequestered from the atmosphere and so "re-release" does not add to net atmospheric greenhouse gas concentrations (Biomass Energy Center 2008a). In assessing the extent of greenhouse gas reductions it is essential to consider the entire life-cycle of the biomass production system to account for activities that may reduce the net benefit. Additionally for a bioenergy system one needs to take into account more than just greenhouse gas balances. Biomass is a solid fuel and utilization invariably results in a variety of other environmental impacts, including airborne emissions of pollutants such as NO_x and particulates (Biomass Energy Center 2008b). There is also an increasing awareness of the wider socio-economic aspects of bioenergy systems at the conversion plant and upstream during fuel production.

Uniquely within the renewables sector biomass is capable of servicing all 3 major energy demand segments: heat, electricity, and transport fuel. However, inherent land constraints on indigenous biomass supply and market constraints on imports mean that it is important to maximize the benefits obtained from the limited resource. For instance, waste wood which often is disposed off at land-fills leading to biogenic GHG emissions can be a good source of fuel to provide space and water heat (Energy Saving Trust 2009). However to date UK energy policy has been focused on encouraging electricity from biomass and European initiatives have spear-headed biofuels development (BERR 2009a). Only within the last two years has attention turned to heat, with the UK government currently considering whether a renewable heat incentive or renewable heat obligation would work better to stimulate the market (BERR 2009a). Currently support exists in the form of capital grants, tax breaks in the form of enhanced capital allowances etc. which have been discussed further in Chapter 4. It is important at this stage to determine whether these policy measures are achieving their goal of promoting biomass heating by providing them with a level playing field to compete with the existing fossil fuel based technologies. This will depend to a large extent on the cost incurred in generating a MWh of heat from biomass sources in comparison to that from fossil fuels and to what extent policy mechanisms are helping bring down the costs for biomass.

Incentives however will only make economic sense if the biomass installations actually result in net GHG savings (in comparison to the alternatives available) in quantities which can justify the cost of the support mechanisms. EU ETS provides us with variable market price at which a tonne of CO_2 is traded. Although a comparison with the value of support mechanisms for a tonne of CO_2 saved with the EU ETS trading price will be informative, the fact is that the biomass heating technologies discussed here are not covered in the list of installations included in the EU ETS (Biomass Energy Center 2008c).

1.2 Scope of the Research

This study aims to determine the effect of current and planned UK energy and environmental policy for the expansion of biomass heating in the UK. This is done by examining two very realistic scenarios. These were chosen to facilitate examination of a number of different relevant issues, including the reference system being replaced, the institutional frameworks within which investments are made, operating modes and environmental performance. They are:

Scenario 1. Replacement of existing individual domestic oil-fired boilers nearing the end of their useful life in rural areas off-gas grid with individual domestic wood-pellet fired boilers.

Scenario 2. Installation of a district heating system to serve the base load of a new-build housing estate of around 100 dwellings at the edge of a small town in conjunction with a gas fired heating system to meet the peak demands, instead of the load being met solely by a gas fired boiler.

The following hypotheses were tested for the two scenarios:

1. The existing biomass based heating support mechanisms in the UK provide a net economic benefit to end-users per MWh of heat generated over the lifetime of the biomass boilers in comparison to a fossil fuel based option. We use an indicative price of £40 per MWh of heat generated from an oil fired heating system.

2. The installations proposed in the two scenarios will lead to a net GHG saving in comparison to fossil fuel alternatives and the value of the existing policy support mechanisms for a tonne of CO_2 mitigated in this non-EU ETS sector is significantly less than the price at which it is being traded currently in the EU-ETS sector.

The objectives were to evaluate the 2 realistic option based scenarios across key environmental and socio-economic priorities and examine the extent to which current and planned UK energy policy could influence whether or not such expansion proceeds. The methodology followed has been discussed further in the following chapter.

Chapter 2

Methodology

In order to fulfill the aim, the objectives encompassed the following:

- Defining fully the 2 scenarios, including the context in which these are likely to occur. For e.g. consideration of main drivers in each case, investment sources etc.

- An environmental assessment of the 2 scenarios which will include identifying the greenhouse gas reduction potential and the primary energy from fossil fuels consumed in each case.

- Generation of a simple spreadsheet-based economic model of each option will be constructed using discounted cash-flow techniques to evaluate the economic viability of each option as well as to determine the value of support provided for each tonne of CO_2 mitigated.

- A review of the relevant existing and proposed policy frameworks will be carried out to identify the incentives offered by the UK government for both these schemes and evaluate their effectiveness.

The environmental assessment and the economic analysis were primarily done using the Biomass Environmental Assessment Tool (BEAT) version 2 ($BEAT_2$) which was developed by AEA in association with North Energy Associates and the Environment Agency. The following section is a brief description of the tool.

2.1 BEAT version 2 ($BEAT_2$)

$BEAT_2$, released in November 2008, is a Microsoft Access ™ based tool which was developed to be helpful in assessing biomass schemes by: providing a comparison of GHG emissions from the proposed plant and fossil fuel based plant, providing information on key potential environmental impacts, identifying potential options for mitigating environmental impacts, and providing an estimate of production costs and of support mechanisms (AEA and North Energy 2008). The tool takes into account the whole life cycle of the technology and the fuel chain by considering all the stages of the fuel chain right from the origin of the biomass to the end use and comes with a full set of default data which can be changed by the user if desired. $BEAT_2$ covers only the first two stages out of six of the official framework of life cycle assessments included in the International Standard ISO 14040 series as it includes just the goal and scope definition and the life cycle inventory analysis (AEA and North Energy 2008). It does not focus on the remaining four which include life cycle impact assessment, life cycle interpretation, reporting, and critical reviewing (AEA and North Energy 2008). The intent of the tool is to provide an easy way to examine different biomass schemes (AEA and North Energy 2008). It is none the less an appropriate tool to examine our hypothesis since it is capable of quantifying the GHG emissions and the economic parameters that we are interested in.

The process chains which were considered for the two scenarios have been explained along with the other aspects of the tool in Chapter 5 where the results have been presented.

Chapter 3

Definition of the two scenarios

3.1 Scenario1: Domestic wood-pellet fired boiler

The replacement of an existing individual domestic oil-fired boiler for space and water heating purposes nearing the end of its useful life is considered in this scenario. The existing system is replaced by a biomass based heating system using wood pellets where otherwise a gas-fired boiler would have been installed. The household is assumed to be located in a rural location and the different parameters which have been used to model the scenario have been selected accordingly.

The energy requirement for the household for space and water heating purposes was assumed to be about 60 GJ a year, which is the average value for an UK household (Boyle 1998). This scenario models a biomass heating system which provides for 100% of this load. In other words a biomass heating system which is able to provide 60GJ of energy per year is installed in the household. In theory this requires a boiler with a minimum thermal input rating of about 12.5kW with a 90% thermal efficiency operating for about 1500hrs ca. a year. However to address peak load requirements (which will be higher than the 12.5 kW value obtained from averaging the total energy over total time of operation) we opt for a 20kW boiler suggested in the Department of Business and Regulatory Reform's Low Carbon Buildings Programme for a three bedroom semi-detached house (BERR 2009b).

For a system of that size the capital cost would be in the range of £5000 to £14000 (BERR 2009b). We consider the low price of £5000 in our case assuming the household opts for the cheapest option and an annual operating and maintenance cost of £250 on top of fuel cost. . The initial investment is to be made by the household with a 30% capital grant from the Department of Energy and Climate Change (DECC)'s Low

Carbon Buildings Programme (LCBP) (BERR 2009c). Once installed the boiler is assumed to have a lifetime of 25 years. A discount rate of 5% and a 10% cost of capital is assumed for the economic calculations. A base case is also considered in this scenario where the entire cost is borne by the household to demonstrate how different policy incentives are helpful.

Other assumptions include the use of clean wood waste for the manufacture of the wood pellets used as fuel in the boiler. Pellets have been considered a source of fuel despite the fact that they require energy to be produced thereby reducing the GHG savings because of their energy density, thereby requiring less storage space, and reliability which are important factors while considering stand alone domestic heaters. The waste is generated from industries like sawmills etc. At source we assume the moisture content of the waste wood to be about 50% and an ash content of 0.5%. The pelletizing plant is assumed to be located near the source of the waste and we consider a distance of 25km in our model. Once the waste wood arrives at the pelletization plant it is chipped and then bulk dried using electric fans and proper ventilation. Through this process the moisture content brought down to 7% prior to the process of pelletization. The pellets are then transported and delivered to the household at a cost of £140 per oven dried tonne (BERR-DTI 2007). We assume that the pelletizing plant is located closer to the source of the waste wood but may not be as close to the domestic household where it is used. Hence we consider a distance of 50 km between the pelletizing plant and the domestic household. The model considers the different savings accrued by avoiding the disposal of this clean wood waste to the nearest landfill site which we assume is located at a distance of about 25km. This includes savings like the emissions from the use of vehicles to transport the waste to the landfill site as well as the associated emissions from the landfill. However the inert waste generated in the form of ash at the end of the combustion of the wood pellets by biomass heating system is assumed to be disposed off along with the municipal waste in the domestic waste stream. This is end user behavioral aspect is assumed because the wood pellets have a dry wood ash content of about 0.5% which would result in the generation of less than 10 kg of ash annually for a system of this size.

A detailed list of the aforesaid and other parameters used in the creation of the model has been presented in Appendix A.

3.2 Scenario 2: District heating using a wood-chip fired boiler for base load

This scenario considers a larger scale biomass heating system with the installation of a district heating system in lieu of a natural gas based system to serve a newly built housing estate of 100 dwellings with a gas fired boiler installed as a backup. We consider this estate near the edge of a small town so that the location is urban. The biomass system to be installed will use wood chips as fuel in this scenario which will bring down the cost of fuel considerably in comparison to the use of wood pellets.

As previously discussed, the average value of energy required for space and water heating purposes for an UK household is 60GJ (Boyle 1998). This will lead to an average heat load of 1667 MWh (approx.). In this scenario we size the boilers so that in actual operation the biomass boiler runs without frequent load changes by providing most of the base load and any surge in requirements during periods of peak demand is met by a fossil fuel fired boiler. This is achieved through a 690kW boiler with an efficiency of 80% and a load factor of 25%. This will generate about 1200MWh in a year. The remaining requirement is met by a 600 kW natural gas boiler. A district heating system installed in 2003 in Lochgilphead for 51 homes for an average heat load of about 930 MWh required a 460 kW wood chip fired biomass boiler with an efficiency of 75 % and a 300 kW oil fired boiler (SDC Scotland 2005). With this configuration it was reported that the boiler operated at a load of below 260 kW at all times (SDC Scotland 2005). We thus feel that our boilers have been aptly sized to meet the base load demand of a 100 household district system.

Such a biomass system will cost around £345,000, based on an average value of about £500 per kWt (Carbon Trust 2009a). We assume an annual maintenance cost of about £17,500, estimated based on a maintenance cost of £14,000 reported for the Lochgilphead district heating system for 51 homes which used the general rule of thumb of considering this as 5% of the capital cost (SDC Scotland 2005). The initial investment is to be made by the housing developer with a capital grant from the

Department of Energy and Climate Change (DECC)'s Bio-Energy Capital Grants Scheme (DECC 2009a). This scheme provides a grant with a variable rate of up to 40% of the difference in cost of installing the biomass boiler compared to installing the fossil fuel alternative. Once installed the boiler is assumed to have a lifetime of 25 years. As in scenario 1, a discount rate of 5% and a 10% cost of capital is assumed for the economic calculations. In addition to that such a scheme qualifies for an enhanced tax relief of 100 per cent for the first-year which allows the full cost of an investment to be written off against the taxable profits of the period in which it is made. This effectively amounts to a capital cost offset of 21% at current corporation tax rates for a company with an annual profit of less than £300,000 (HM Treasury 2003), which has been assumed in the case of the investor in our case. As in the previous scenario a base case is included with no policy intervention to demonstrate the effect of policy measures

In this scenario we assume wood chips to be generated from residues of forestry operations in the UK which include the branches and tops of the trees (brash) removed from the logs when a forest is clear-cut at the end of the rotation period or small trees removed in thinning operations. We expect a chipper to be located close to the forest area and assume that the wood is initially with a moisture content of 50% and it is then chipped and dried to a moisture content of about 25% while in storage with the use of fans. The estate is assumed to be located within a distance of 10 km and the chips are delivered at a rate of £60 per tonne. In this scenario the waste generated in the form of ash at the end of the combustion of the wood chips by the biomass heating system, unlike Scenario 1 is in larger quantities, and is assumed to be applied as a fertilizer to land ensuring return of nutrients to soil and thereby avoiding the need for the application of lime and giving us GHG credits equivalent to the amount involved in the manufacture of the lime. Unlike the previous scenario, we consider the forestry residues to be a valuable traded and not as waste wood which otherwise would have been destined for a landfill since to guarantee its supply a contract will be placed with the forester. Hence we did not assume any credit for avoided greenhouse gas emissions from land-filling of the waste material.

A detailed list of the aforesaid and other parameters used in the creation of the model has been presented in Appendix B.

Chapter 4

Literature Review

4.1 UK energy and environmental policy for biomass heating options

Almost half of all UK's CO_2 emissions arise from the use of heat. That is energy used for space and water heating, industrial process heating, industrial drying and similar purposes (BERR 2009d). The renewable heat market in the UK has not been central to policy measures and incentive mechanisms implemented up until a couple of years ago (BERR 2009a). This resulted in a less than 1% share of renewable sources in the total heat demand in the residential commercial and the industrial sectors in 2005 (Biomass Task Force 2005). However, in March 2007 EU leaders signed a binding EU-wide target to source 20% of their energy needs from renewable which includes biomass by 2020 (EurActiv 2007). Accordingly each EU member state is required to have a national target and a National Action Plan (NAP) for the use of renewable in different sectors including heat. The proposed UK share of this target would be to achieve 15% of the UK's energy from renewables by 2020. This is equivalent to almost a ten-fold increase in renewable energy consumption from current levels (BERR 2008a). With these targets in mind there has been an increasing focus on biomass heating options with the most recent being the EA study released in April entitled "Biomass: Carbon sink or Carbon sinner" where it analyzed the GHG emissions from the production and the use of biomass to generate electricity and heat in comparison with coal and gas and reported the possibility of emission reduction by several million tonnes of GHG per year using good practice (2009). The EA study was developed with $BEAT_2$ the same tool used in this report.

In the UK, there is indeed much potential for biomass in the efforts to mitigate GHG emissions and more importantly reach the 2020 target of 15%. This is evident from

Figure 4-1 which shows the potential for renewable heat in the UK and it is seen that biomass in the residential sector makes up the largest proportion in it (Figure 4-2). To materialize this potential a correct mix of policy measures and regulation is essential and the in fact the continuity of policy instruments have been found to be critical in supporting any bio-energy industry (Thornley and Cooper 2008). The existing policy instruments focusing mainly on financial support mechanisms in the UK have been summarized in Table 4-1 and subsequently discussed in more detail. Non-financial policy support mechanisms are also discussed.

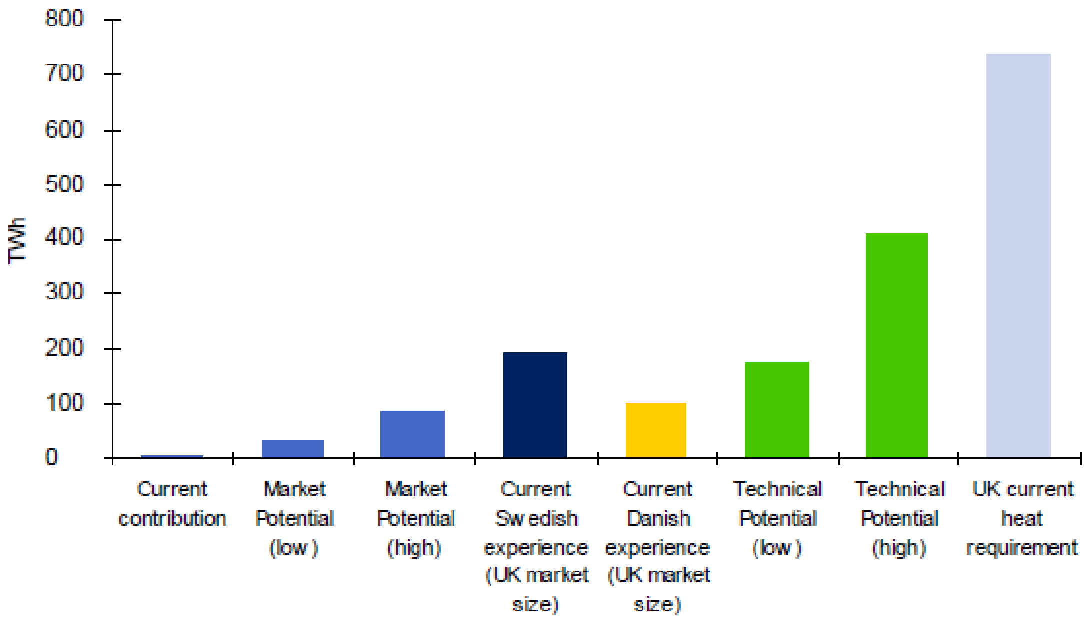


Figure 4-1: Market potential for renewable heat in the UK *(Source: Ernst and Young 2007)*

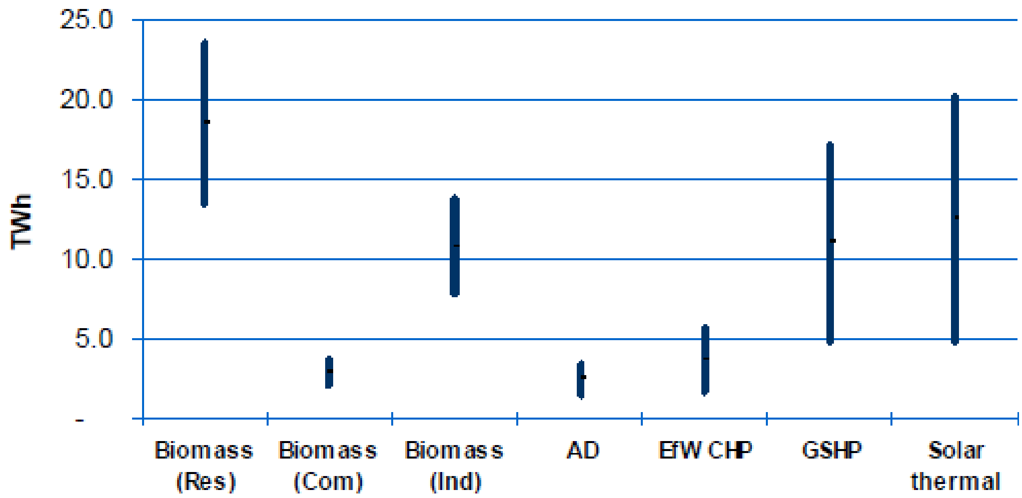


Figure 4-2: Market potential for renewable heat in the UK by technology *(Source: Ernst and Young 2007)*

Table 4-1: Current and planned financial support mechanisms applicable to biomass based systems in the UK. *(For References please see individual descriptions that follow the Table)*

Policy Mechanism	Year
Taxation (various incentives)	2001: Enhanced Capital Allowance 2006: Zero or reduced VAT on micro-generation technologies 2007: Zero stamp duty on zero carbon homes
Renewables Obligation (RO)	2002
European Union Emissions Trading Scheme (EU ETS)	2005
Capital Grants (Bio-energy)	Funding announced 2006 (currently fifth round ongoing)
Low Carbon Buildings Programme (LCBP)	2006 (Phase 1)
Carbon Emissions Reduction Target (CERT)	2008 (Energy Supplier Obligation began in 2002, CERT is its third phase)
Carbon Reduction Commitment	Scheme starts April 2010
Renewable Heat Incentive	Expected by 2011. First consultation to finalize the details of the scheme set for the summer of 2009

4.1.1 Taxation

A number of different tax breaks are included here which offer incentives upon installation of renewable energy technologies. The Enhanced Capital Allowance (ECA) for instance enables businesses to claim 100% of their capital allowances in the first year on their spending on qualified plant and machinery (Carbon Trust 2009b). This allows businesses to write off the whole of the capital cost of their investment in the qualifying technologies against their taxable profits in the period during which the investment is made. The qualifying plant and machinery in ECA are grouped under three schemes which are: energy-saving plant and machinery, low carbon dioxide emission cars and natural gas and hydrogen refueling infrastructure and, water conservation plant and machinery (Carbon Trust 2009b). In case the company is unable to make any profit during that period and actually makes a loss then it can surrender to the government the losses attributable to the ECAs in return for a cash payment. In this way the company can still earn 19% of the loss, however the maximum credit claimable is capped and is limited by the total of the company's Pay As You Earn (PAYE) and national insurance payments for the year or, if greater, £250,000 (Carbon Trust 2009c). An ECA for the developer of the district heating system was considered in Scenario 2 of this study.

The zero or reduced Value Added Tax (VAT) on micro-generation technologies was part of the Microgeneration Strategy that was released by the Department of Business Enterprise and Regulatory Reform (BERR) in 2006 (BERR 2008b). The Microgeneration Strategy was launched with the objective of creating the conditions for micro-generation to become a realistic alternative or supplementary source of energy generation and consisted of 25 actions to tackle the barriers facing microgeneration. The zero or reduced VAT was one of the actions and in it microgeneration technologies pay a reduced VAT of 5% compared to 17.5% (BERR 2008b).

The zero stamp duty relief on zero-carbon homes was launched to help kick start the market for zero-carbon homes by providing this as a fiscal incentive. It was also aimed at encouraging microgeneration technologies just like the reduced VAT strategy and thereby enhance the level of public awareness on the benefits of living in zero-carbon homes. This is however applicable to residential transactions (individuals) and not for commercial ones (businesses). In this relief tax liability is exempted when a house costs less than £500,000, and £15,000 reduction in tax liability is provided to all homes worth more than £500,000 (HM Treasury 2007). Biomass systems cannot solely make a home carbon neutral and hence this relief cannot be applicable to the systems considered in this study. This relief however does offer the potential to be applied in conjunction with other measures and have been discussed further in Chapter 7 on Recommendations.

4.1.2 Renewables Obligation (RO)

The RO made it mandatory for electricity suppliers to source a specific and annually increasing percentage of the electricity they supply from renewable sources. It was preceded by the Non Fossil Fuel Obligation (NFFO) as the major tool used by the government to encourage the growth of the renewable energy industry. Currently the RO for electricity suppliers is 9.1% for 2008/09 and will rise to 15.4% by 2015/16 (OPSI 2006). The suppliers get a tradeable certificate called the 'Renewables Obligation Certificate (ROC)' for each MWh they generate from renewable sources. The suppliers can meet their obligation in three ways: by acquiring ROCs, by paying a buy-out price equivalent to £35.76 per MWh (2008/09) and which is rising each year with retail price and/or finally through a combination of the ROCs and paying a buy-out price (BERR 2009e). Under the RO, it has been proposed that different technologies are placed in different bands so that the suppliers can be given more than 1 ROC per MWh generated for certain technologies (Ernst and Young 2007). This can be instrumental in encouraging the development of specific technologies which are less carbon intense. However RO will not be applicable in the case of dedicated heat boilers and can be applied only if it is a combined heat and power (CHP) plant.

4.1.3 EU Emissions Trading Scheme (EU ETS)

The EU ETS, the first scheme of its kind in the world is a Europe wide scheme which aims to reduce emissions of carbon dioxide by putting a price on carbon that businesses use and thereby creating a market for it. It has been in place since 2005. It aims to bring down the GHG emissions of Europe to 8% below the 1990 levels under the Kyoto protocol (DEFRA 2007). The first phase of the scheme ran from 2005 till 2007 and it is currently in its second phase. Under it, member states need to come up with individual National Allocation Plans which set a 'cap' to the total amount of emissions from installations covered in the scheme. The NAPs however need to be first approved by the European Commission (EC). The cap limit is then converted into allowances with 1 allowance equal to 1 tonne of CO_2. This is then distributed to the installations. The installations then are required to monitor and report their emissions and then at the end of the year surrender their allowances to account for their emissions. They may sell surplus allowances or buy additional ones to balance out their emissions. As of April 2009, CO_2 was trading at about €15 per tonne, down from about €35, a tonne during July 2008 (European Climate Exchange 2009). The EU ETS scheme covers installations such as combustion plants with a rated thermal input of more than 20MW, iron and steel plants, oil refineries, cement, glass, lime, bricks, ceramics, pulp and paper factories (Biomass Energy Center 2008c). Hence the EU ETS was not applicable to the two scenarios under consideration in this study. However EU ETS can be instrumental in encouraging biomass heat since participants can invest in it in addition to their other investments so that they can offset some of their emissions in order to meet or exceed their allowance. The potential limitations that exist include the fact that there is not much certainty in the price of the allowances across different phases and hence it is difficult to generate the cost-benefit analysis of investments in different technologies.

4.1.4 Capital Grants

The Bio-energy Capital Grants scheme, currently in its fifth round of operation and has funding from the Department of Energy and Climate Change (DECC) supports the installation of biomass fuelled heat and combined heat and power (CHP) projects in the industrial, commercial and community sectors of England (BERR 2009f). For the years 2009-2011, the scheme is worth £12 million (Biomass Energy Center 2008). It is part of the UK Environmental Transformation Fund (ETF) which aims to bring forward the demonstration and deployment of low carbon energy and energy efficiency technologies

(DEFRA 2009a). It is not applicable to householders and individuals. The technologies that are eligible for the grant include biomass heat boilers and CHP equipment including anaerobic digesters for heat-only or CHP (DECC 2009a). Under this scheme a variable rate of up to 40% of the difference in cost of installing the biomass boiler or CHP plant compared to installing the fossil fuel alternative is provided with a maximum single grant of up to £500,000 per installation (DECC 2009a). Scenario 2 in our case was able to benefit from this scheme.

4.1.5 Low Carbon Buildings Programme (LCBP)

The LCBP scheme's Phase 1 was launched on 1 April 2006 was part of the measures outlined in BERRs Microgeneration Strategy published in March 2006 (BERR 2009g). It is managed by the Energy Saving Trust on behalf of BERR. The LCBP fills the void that was left by the Bio-energy Capital Grants scheme by making householders eligible as well for financial support. It is also open to public, not for profit and commercial organizations across the UK (except the Channel Islands and the Isle of Man) (BERR 2009g). At present, Phase 1 is solely for householders since all grants to public, not for profit and commercial organizations have been allocated. New applications for them are being accepted as part of Phase 2. The following technologies are currently eligible: solar photovoltaics, wind turbines, small hydro, solar thermal hot water, ground source heat pumps, and bio-energy. For these technologies grants of 20% to 50% of the relevant eligible costs are awarded in respect of equipment and work directly related to the installed system. This includes design of the system, the cost of the plant and/or materials, installation and connection (BERR 2009c). For automated wood pellet fed room heaters/stoves an overall maximum of £600 or 20% of the relevant eligible costs, whichever is the lower is awarded while for Wood fuelled boiler systems it is £1,500 or 30% of the relevant eligible costs (BERR 2009c). Hence we considered this grant for Scenario 1 in this study. In LCBP Phase 2 which excludes householders, biomass based systems are eligible for a grant of up to 50% of the eligible costs excluding VAT (BERR 2008c).

4.1.6 Carbon Emissions Reduction Target (CERT)

The Carbon Emissions Reduction Target (CERT) is a statutory obligation on energy suppliers to achieve carbon targets by encouraging households to take up energy efficiency and low carbon measures by using energy from renewable/microgeneration sources (DEFRA 2009b). CERT is the third and more ambitious three year phase of the Energy Suppliers Obligation (ESO) and is from 2008-2011. The initial two three-year phases were called Energy Efficiency Commitment (EEC). Under CERT, energy suppliers must deliver measures to generate CO_2 savings of 154 Mt which is equivalent to the emissions from about 700,000 homes each year by 2011. This will require an investment from the energy suppliers of about £2.8 billion (DEFRA 2009c).

The obligations set forth by CERT build up on the success of the EECs. During the first EEC which ran from 2002-2005, £600m investment in energy efficiency measures was stimulated and benefits to householders in excess of £3 billion was delivered (OPSI 2008). Part of the obligation under CERT is that suppliers focus 40% of their activity on a 'Priority Group' of vulnerable and low income households. By its obligations CERT is expected to help alleviate fuel poverty from households. Currently CERT is in a phase of consultation on whether to be amended into the Prime Minister's £1 billion Home Energy Saving Programme. If the proposal goes through there can be a possible increase in the supplier investment by about 20% of the target or about £560 million by 2011. It will also mean that the scheme's lifetime carbon savings will increase by 31MtCO_2 to 185 MtCO_2 (DEFRA 2009c).

4.1.7 Carbon Reduction Commitment

The Carbon Reduction Commitment is an UK-wide scheme which officially starts in April 2010 is directed at reducing the level of carbon emissions by non-energy intensive organizations, which generate about one third of the UK CO_2 emissions, by approximately 1.2 million tonnes of CO_2 per year by 2020 (Carbon Trust 2009d). The CRC will be a mandatory emissions trading scheme and it will target the organizations not included in the EU ETS or other Climate Change Agreements and thereby fill the void there. Organizations like supermarkets, office-based corporations, government departments and large local authorities will come under this scheme (Carbon Trust 2009d). In fixed terms of energy usage, the CRC will cover all organizations whose electricity consumption through half hourly meters is greater than 6,000MWh/yr which is equivalent to an annual electricity bill of ~£500k (Carbon Trust 2009d). In this scheme allowances will be sold initially introductory phase starting April 2010 and will be auctioned from April 2013 and the number of credits will diminish over time. Similar to the EU ETS program here at the end of the year the company performance will be summarized outlining the best and the worst performers and the auction revenues will be recycled back to the participants depending on their performance. This scheme therefore has the potential to strengthen the corporate social responsibility (CSR) of the participants in addition to addressing issues of efficient energy use and improved metering (Carbon Trust 2009d). The benefit to the participating companies is expected to be about £1 billion by 2020 (DEFRA 2009d).

4.1.8 Renewable Heat Incentive (RHI)

The Energy Act of 2008 allows the setting up of the RHI which aims to bring this incentive to all levels of operation be it a household or at the industrial scale in the UK. The details of the scheme are yet to be finalized but consultations will begin in the summer of 2009 on all aspects of it. Apart from the fact that the incentive will apply to generation of renewable heat at all scales, the incentive is expected to be banded by size or technology. It will include a wide range of heat technologies like biomass, solar hot water, air and ground source heat pumps, biomass CHP, biogas produced from anaerobic digestion, and biomethane injected into the gas grid (BERR 2009h). There is a possibility that for households the support payments may be provided as a lump sum up front. The scheme will be funded by a levy on suppliers of fossil fuel for heat which will mainly be licensed gas suppliers but may also include coal, heating oil, liquefied Petroleum Gas (LPG) etc. It is expected to be in place by April 2011 (BERR 2009h)

4.1.9 Non-financial policy support mechanisms

In addition to financial support mechanisms, policy based mechanisms which are non-financial in nature can be helpful in breaking down of the barriers to deployment as well as to stimulate the demand of renewable heat. These mechanisms include subsidies of the infrastructure costs and or other legislation, procurement policies of public utilities, procurement policies of national and local governments, building regulations, planning requirements, and specific interventions to create networks like producer networks for biofuels etc (Ernst and Young 2007). It took Denmark a period of 20 years to build a district heat transmission network covering 60% of the domestic users with the help of proper legislation and it can be assumed that a similar time-frame might be required in the case of the UK (Ernst and Young 2007). This was done through the enforcement of a legislation which encouraged district heating networks in Denmark (Ernst and Young 2007). In addition to that changes in the procurement policy by the government can go a long way in encouraging the use of heat from renewable sources which are less carbon intensive. Similarly planning and building regulations can influence the way energy is supplied as well as consumed by imposing standard on new buildings being built or to reach certain levels of energy efficiency in existing buildings. For instance the Merton ruling in the UK was the first planning guidance to formalize the Government's renewable energy targets in its Unitary Development Plan (UDP). It set a target of 10% use of onsite renewable energy for any development of more than 10 houses in the borough (Ernst and Young 2007). In addition to that specific interventions like grants for crops like miscanthus and short rotation coppice (SRC) through the Energy Crops Scheme (ECS) influences the choice growers in their selection of crops to cultivate. Similar interventions in the development of a supply chain for the use of biomass from cultivation to the final use in the boiler can be critical in encouraging this technology (Ernst and Young 2007).

4.1.10 Open Consultations on Future Strategy

In an effort to reduce the emissions of CO_2 by 80% by the year 2050, the government released three papers on February 12, 2009 which set out its near and longer term proposals for mobilizing and supporting this change (BERR 2009d). These include the Heat and Energy Saving Strategy (HES) Consultation, the Community Energy Savings Programme (CESP) and an amendment to the Carbon Emissions Reduction Target (CERT) which has been discussed earlier (BERR 2009d). The consultations opened on the 12th of February and close on the 8th of May 2009 (DECC 2009b).

The HES Consultation have been jointly published by the Department of Energy and Climate Change (DECC) and the Department for Communities and Local Government (CLG) (DECC 2009b). This document sets out the governments vision up to 2020 and beyond and the policies aim to reduce the annual emission by up to 44 million tonnes of CO_2 by 2020 which is equivalent to a 30% reduction compared to the 2006 household emission levels (DECC 2009b). Amongst the various proposals made in the consultation is the promotion of district heating in suitable communities by removing barriers. This can further help the development of biomass district heating systems.

The Community Energy Saving Programme proposes to place an obligation on energy suppliers to meet CO_2 reduction targets by providing energy efficient measures including district heating to domestic consumers in areas with high levels of low incomes. The program aims at delivering around £350 million worth of energy efficiency packages (DECC 2009c).

4.2 Some notable non-UK policy measures

Having focused on the policy mechanisms existing in the UK for the support of renewable heat from biomass we now look at some other country examples of different policy support mechanisms which have been able to achieve significant results and which offer valuable insight into the policy process.

4.2.1 Germany

Germany has already exceeded its 5.75% bio-fuel target for 2010 in 2006 when it achieved 6.3%. This is calculated as the share of renewable consumption to gross final energy consumption. This was achieved through a mix of different policies which include feed-in tariffs for RES-E, market incentives for RES-H and tax exemptions for biofuels resulting in a very dynamic market for RES (EC-DGET 2008). The Market Incentive Programme (MAP) which provides subsidies mainly for RES-H has produced excellent results for small-scale biomass heat generation as well as solar and thermal. Its budget was increased significantly from €39 million in 2006 to €213 million in 2007 (EC-DGET 2008). The scheme was enacted by the National Government and is administered by the Federal Government for the Environment, Natural Conservation and Nuclear Safety. MAP provides benefits in the form of incentives to individuals as well for investments in RES. Apart from solar and geothermal technologies various biomass based systems are supported which includes biomass heaters starting at an installed capacity of $8kW_{th}$ (EBA 2006). The devices need to meet the standards for emissions set out by the 1st Federal Emission Control Act (EBA 2006). For devices up to 1000 kW_{th} the emissions should not be more than 250 mg/m^3 carbon monoxide and 50 mg/m^3 dust (EBA 2006). The energy efficiency has to be at least 88%. For systems greater that 1000 kW_{th}, the Technical Instructions on Air Quality Control (TA Luft) needs to be fulfilled in relation to 1st Federal Emission Control Act (EBA 2006). In 2007 automatic biomass boilers up to 100kW received grants of €24 per kW for wood-pellet furnaces/boilers and combined pellet/split log boilers (IEA 2008). For systems of wood chip boilers a grant of €500 per system and for wood gasification boilers between 15 kW and 30 kW a grant of €750/system were provided (IEA 2008). Large scale solar collectors and biomass systems greater than 100 kW may receive a bonus for using innovative technologies, in addition to a basic grant (IEA 2008). Figure 4-3 shows the growth of the biomass system in Germany from 2000 till October 2005 as a result of MAP. We see a four-fold increase in the total amount of biomass heating applications that were supported by the MAP. MAP is currently in force with a budget of €400 million for the year 2009 (IEA 2008).

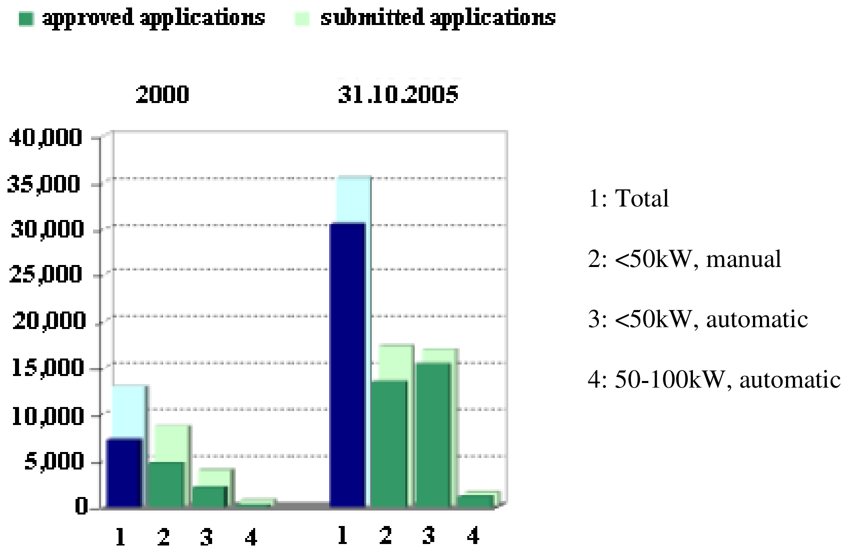


Figure 4-3: Development of applications for biomass heating systems less than an installed capacity of 100 kW_{th} *(Adapted from EBA 2006 (original source: BAFA, 2005))*

During the period from January 2002 till July 2004 about three quarter of MAP support was given for the promotion of solar thermal collectors, however nearly 78% of the CO_2 savings were from the bio-energy facilities which have been charted in Table 4-2 (EBA 2006).

Table 4-2: CO_2-mitigation of MAP supported bioenergy facilities from January 2002 to July 2004 *(Adapted from EBA 2006 (Original source: BMU, 2005))*

Year of	2002 [t/a]	2003 [t/a]	30.06.2004	Total [t/a]
Biomass < 100	40,737	43,795	11,167	95,699
Biomass > 100	69,501	101,506	13,475	184,482
Biogas	73,947	57,535	17,515	149,197
Total				**429,378**

The calculation of the savings is dependent to a great deal on whether the whole life cycle emissions were taken into consideration while determining the CO_2 mitigated. The values in Table 4-2 are from the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety of Germany published in a report by the European

Biomass Association and have been included only as a reference of the amount of CO_2 mitigation claimed by the agency (EBA 2006).

4.2.2 Sweden

In Sweden, 43% of the energy supply comes from renewable energy which is more than in most EU countries (Swedish Official Website 2009). This was achieved primarily through the Swedish energy taxation policy which was aimed at increasing the use of biofuels, the improvement of efficiency and the creation of conditions favorable for the indigenous production of electricity (EBA 2006). The carbon dioxide tax was introduced in 1991 and it is levied on CO_2 from all sources except biofuels (and peat). In 2004 this was 91ore/kg (about € 0.09/kg) of CO_2 emitted (EBA 2006). This tax is applicable to private individuals using fossil fuels for heating and transport as well as on companies. The tax was increased in 2000 through the transfer of 30 billion SEK (€2.9 billion) of tax revenues over a ten year period from the employment sector thereby offsetting a corresponding reduction in it (EBA 2006). The carbon dioxide tax was raised by 20% beginning 2004 however with reductions to ensure that it remains unchanged for sectors like manufacturing industry, agriculture, forestry etc (EBA 2006). In addition to the CO_2 tax, a SO_2 tax was incorporated in 1991 which applied on coal and peat as well as an environment levy on NO_x emissions which came into effect in 1992 (EBA 2006). This has led to an increased use of biofuels with a declining use of other fossil based fuels as can be seen in Figure 4-4: The historical use of oil, biofuel, electricity, heat pumps and different combinations of those in detached houses in Sweden from 1987 till 2005 *(Source: Höglund 2008)* .

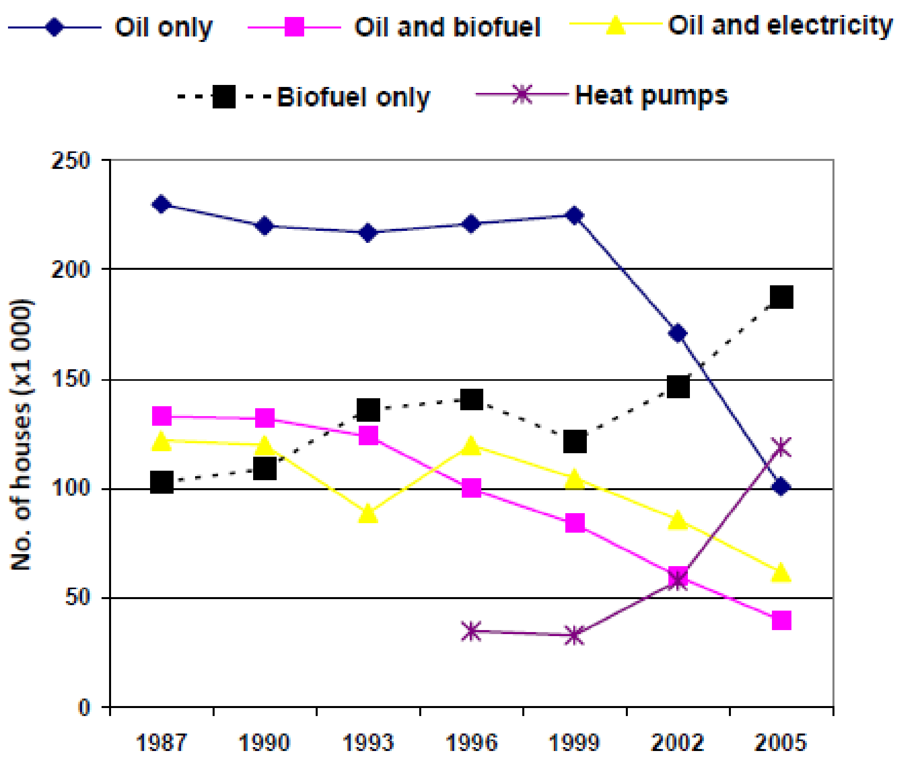


Figure 4-4: The historical use of oil, biofuel, electricity, heat pumps and different combinations of those in detached houses in Sweden from 1987 till 2005 *(Source: Höglund 2008)*

The effect of the carbon tax was directly realized in the pellet industry as the number of pellet producers increased from two in 1990 to 30 in 2003, and the annual production increased from 10 000 tonnes in 1990 to one million tonnes in 2004 (Höglund 2008). Table 4-3 charts the change in the amount of oil and biofuels used in three years and we can see the significant increase in the usage of biofuels and a corresponding use in gas oil over the period of 1990-2003.

Table 4-3: The use of different fuels in Sweden since the introduction of the carbon tax in 1991 *(Source: EBA 2006)*

Type of Fuel	1990	2002	2003	Change 2002-2003	Change 1990-2003
Medium-heavy fuel oil	3,004 Mm^3	2,923 Mm^3	3,858 Mm^3	32%	28%
Gas oil	3788 Mm^3	2,667 Mm^3	2, 898 Mm^3	9%	-23%
Biofuels	67 TWh	99 TWh	103 TWh	4%	54%

The taxation of fossil fuels has led to biomass based option to be the cheapest one as can be seen from Figure 4-5 where pellets are the cheapest in terms or end use plotted in SEK per kWh. As far as revenues are concerned, about 23.7 billion SEK (€2.3 billion) and about 136 million SEK (€13 million) from the sulphur tax in 2003 (EBA 2006). The total revenues from the Swedish energy taxes in the same year was 62.2 billion SEK (€6 billion) which was about 10.2% of the total national tax revenues (EBA 2006).

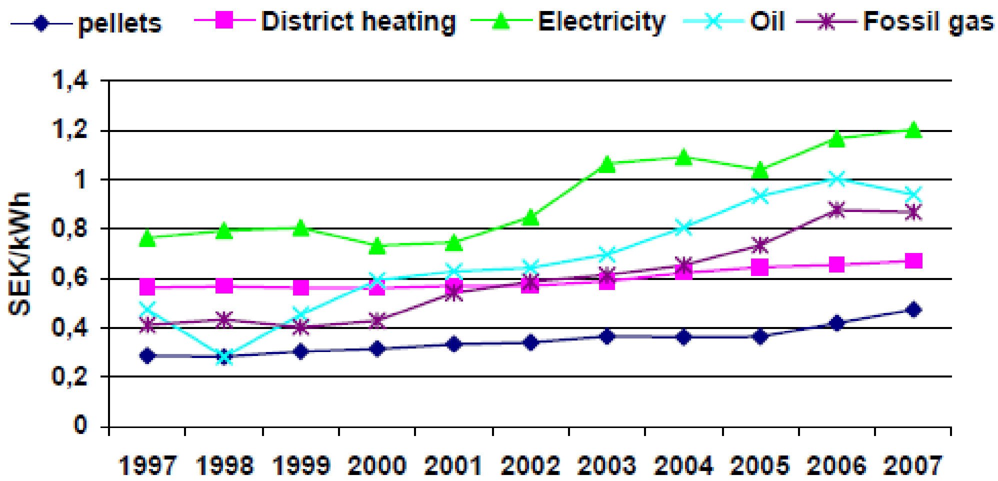


Figure 4-5: Price development of 5 different energy sources from 1997 till 2007 (SEK/kWh incl. taxes and duties). The price includes only running energy prices; investment- and maintenance costs for heating systems are not taken into consideration *(Source: Höglund 2008)*

In addition to the taxation of fossil fuels Sweden provides tax deductions for biofuel appliances applicable to single families, farm houses and houses that have not more than two apartments with the precondition that the heat is distributed through a central heated water pipe network. The scheme came into effect in 1 January 2004. The tax deduction is 30 % of costs exceeding 10000 SEK (1075 EUR) and is limited to maximum 15000 SEK (€1430) per house. This is administered by the National Tax Agency (Skatteverket) (EBA 2006).

Chapter 5

Analysis of the scenarios in the light of existing policies

The two realistic scenarios described in Chapter 2 are now examined across key environmental and economic considerations using $BEAT_2$ to determine the effectiveness of the existing and planned support mechanisms. A description of the process chain considered for each scenario is presented first followed by the results and the analysis.

5.1 Scenario 1: Domestic wood-pellet fired boiler

5.1.1 The Process Chain

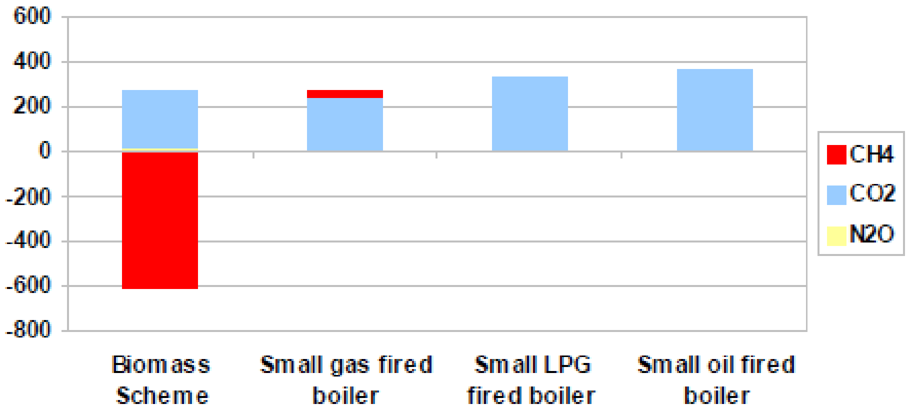
The process chain considered here starts from the point of generation of the waste wood chunks and ends with the provision of heat at the household. It includes all the stages in between which broadly include transportation of the wood chunks to the point where they are chipped, their conversion into pellets, subsequent transportation to the point where they are used and the final ash disposal with many associated sub-stages related to these included as well. The scenario was modeled using a reference system where the wastes which were used to manufacture the pellets were otherwise destined for a landfill. Hence the process chain includes the avoided direct biogenic emissions as well as the process inputs for the construction, operation and the decommissioning of the landfill along with energy recovery from the landfill. The energy recovery from the landfill involves collection of the gas generated and its subsequent use in the generation of electricity which then in turn displaces conventional fossil fuels for the generation of electricity.

5.1.2 Environmental Assessment

The environmental assessment focused mainly on two parameters: namely the net GHG emissions and the net primary energy from fossil fuels required to generate a MWh of heat from the different systems considered. A life cycle analysis of the emissions from the proposed installation of a biomass boiler using wood pellets as fuel in the household is compared to that from fossil fuel based boilers using natural gas, LPG and oil.

It was found that the use of pellets generated from waste wood can save 712.3 kg CO_2 per MWh of heat generated in comparison to the same amount of heat generated from an oil fired plant which is typical in rural areas of the UK.

This refers to a reduction in net emissions involving CH_4, CO_2 and N_2O and is primarily realized through biogenic CH_4 savings in comparison to the reference system as can be seen from Figure 5-1. The graph shows the emissions as kg CO_2 equivalent per MWh of heat generated considering a global warming potential of 23 for CH_4 and 296 for N_2O as recommended by the IPCC Third Assessment Report (AEA and North Energy 2008). The CH_4 savings are generated by avoiding the disposal of the clean wood waste into landfills resulting in biogenic CH_4 emissions (Figure 5-1, shown in red) and instead utilizing them for the manufacture of the pellets. This leads to a negative net GHG emission for each MWh of heat generated in this scenario. The CO_2 emissions are roughly similar from the four different boilers considered. N_2O in the case of the biomass boiler which is generated primarily during the combustion of the pellets is seen to be higher than the others. It is seen from Figure 5-2 that the actual emissions result from the processing of the feedstock, its transport and the subsequent conversion of the pellets for heat in the boiler. Significant savings are also seen in comparison to a gas and an LPG fired boiler as can be seen from the inset table in Figure 5-1.



Source:	CO2	CH4	N2O	Total:	Range:
		kg CO2 eq/MWh			+/-
Biomass Scheme	259.5	-607.1	10.5	-337.1	15.5
Small gas fired boiler	242.0	25.3	2.6	269.9	
Small LPG fired boiler	318.9	8.6	2.6	330.1	
Small oil fired boiler	359.8	0.1	0.0	375.2	

Figure 5-1: Comparison of GHG's emitted in kg CO_2 equivalent per MWh of heat generated in case of a pellet fired biomass and other fossil fuel boilers.

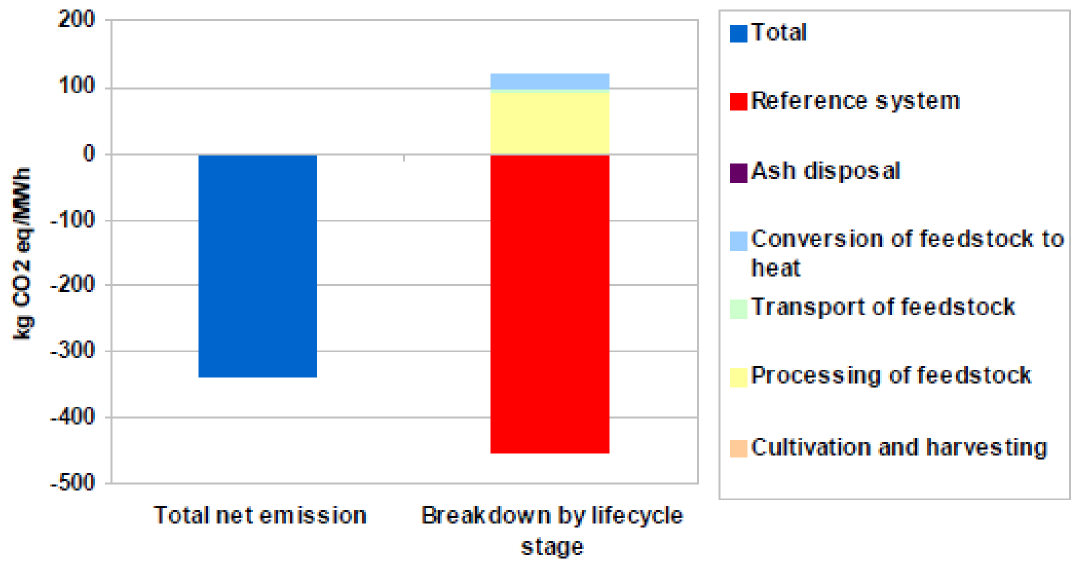
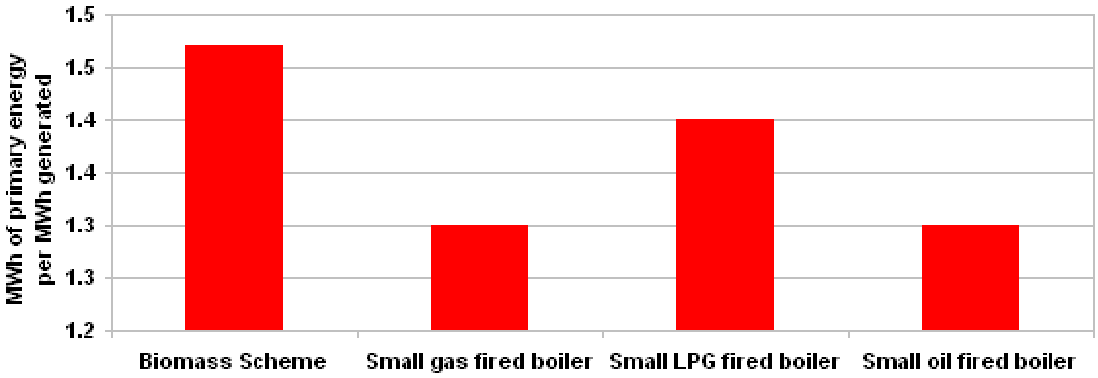


Figure 5-2: Graphical breakdown of the GHG's emitted (kg CO_2 equivalent per MWh of heat generated) in the case of a pellet fired biomass across different stages in its life cycle.

Table 5-1: Actual breakdown of the GHG emissions in kg CO_2 equivalent per MWh of heat generated in case of a pellet fired biomass boiler across different stages in its life cycle.

Activity	CO_2	CH_4	N_2O	Total GHG	Primary energy required MWh/MWh
Conversion of feedstock to heat	10.7	0.5	7.5	18.7	0.1
Ash disposal	0.0	0.0	0.0	0.0	0.0
Processing of feedstock	88.9	4.8	1.1	94.8	0.5
Transport of feedstock	3.5	0.1	0.2	3.8	0.0
Reference system	156.5	-612.5	1.6	-454.3	0.9
TOTAL	259.5	-607.1	10.5	-337.1	1.5

It is evident that the GHG savings from a pellet based biomass boiler can only occur if the pellets are made out of waste wood which would otherwise have been disposed off in a landfill. Using virgin wood for pellet production would not lead to the realization of such GHG savings. However as shown in Table 5-1 using waste wood increases the net primary energy consumed per MWh of heat produced since now with respect to the reference system there is no energy recovery from the landfill (0.9 MWh/MWh). This is a significant addition when we compare the primary energy consumed per MWh of heat generated from other fossil fuel based heating systems as shown in Figure 5-3. The primary energy consumed per MWh includes all fossil fuels used to generate a MWh of heat from biomass which includes direct energy due to the use of fuels (e.g. diesel for tractors) and electricity, the indirect energy associated with the production of materials, equipment, etc., and the energy contained in any feedstocks, such as chemicals and materials derived from fossil fuels.



Source:	Primary energy MWh per MWh:
Biomass Scheme	1.5
Small gas fired boiler	1.3
Small LPG fired boiler	1.4
Small oil fired boiler	1.3

Figure 5-3: Comparison of primary fossil fuel used per MWh of heat produced by the pellet fired biomass boiler and other fossil fuel fired boilers.

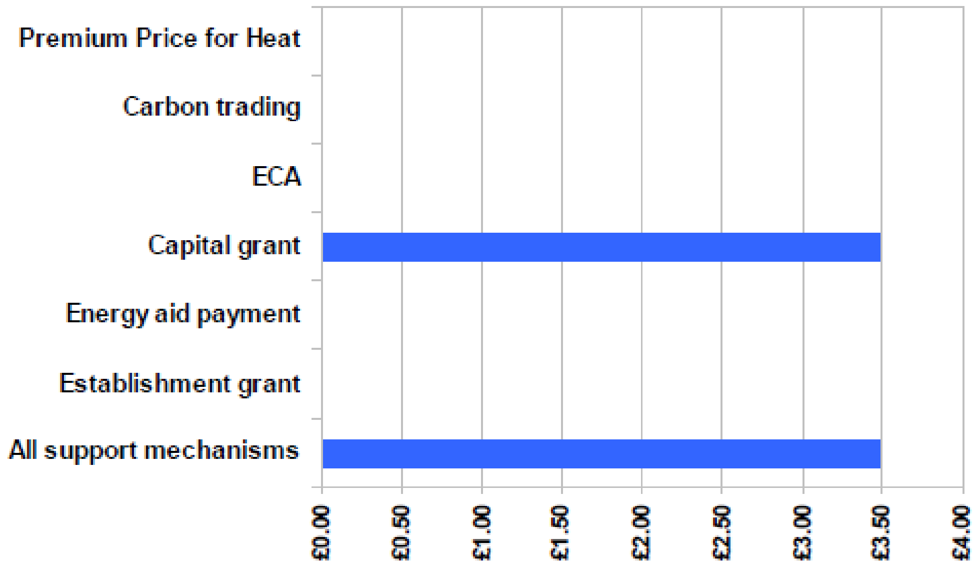
5.1.3 Economic Assessment

With an assumed lifetime of 25 years for the biomass boiler and a 5% and a 10% discount rate and a cost of capital respectively and considering other costs (for more details on the assumptions please refer Appendix A), the Net Present Value (NPV) of the scheme outlined in Scenario 1 was determined using $BEAT_2$. The NPV was determined for two cases: one without any support mechanisms and one with the existing support of a capital grant of 30% of the capital costs. The plant lifetime output of the plant was determined to be 710 MWh and the price of heat production for Scenario 1 was calculated (Table 5-2). The indicative price of heat per MWh from an oil fired boiler is shown as well. It is evident that the biomass boiler is the cheaper option even without any support mechanism.

Table 5-2: Price of heat production from the wood-pellet fired biomass boiler (Scenario 1) with and without support mechanisms and from an oil fired boiler.

Scenario 1 (price per MWh heat in £)	
No support mechanisms	34.22
With currently available support	30.71
Indicative price of heat from an oil fired boiler (exc duty)	40.00

The cheaper price per MWh of heat generated from the biomass scheme is encouraging but it does raise the issue of whether this price difference will be enough to encourage a household to make the switch and whether the GHG savings from such a scheme will be worth the investment. Figure 5-4 shows the cost of support mechanisms per tonne of CO_2 saved to be £3.48 in comparison to an oil fired boiler. This was obtained by dividing the total support provided over the lifetime of the boiler by the total GHG emissions reduction achieved. For Scenario 1, a total of 431 tonnes ca. of GHG reduction was achieved over the lifetime of the plant and the corresponding support was £1500 in the form of a capital grant. In comparison with a gas fired boiler the support per tonne of CO_2 saved increases to £4.46 because of the lower emissions from a gas fired boiler resulting in lesser savings when it is compared to the biomass boiler. The cost of £3.48 (or £4.46) per tonne of CO_2 equivalent is significantly lower than the price at which carbon is being traded currently which is about £13.5 (€15) per tonne ca. (European Climate Exchange 2009). It is important to note here once again that the price of a tonne of carbon has gone down significantly since the last summer when it was trading at 31.5 (€35) per tonne ca. (European Climate Exchange 2009).



All support mechanisms	£3.48
Establishment grant	£0.00
Energy aid payment	£0.00
Capital grant	£3.48
ECA	£0.00
Carbon trading	£0.00
Premium Price for Heat	£0.00

Figure 5-4: Cost of support mechanisms per tonne of CO_2 saved in Scenario 1. The savings have been calculated in comparison to a small oil fired boiler.

The price of a MWh despite being low for the biomass scheme, may not be low enough for a household to be interested in making a switch. This may be due to the fact that they are unwilling to make the initial higher upfront capital investment to install a biomass system despite the fact that over its life-time it will be cheaper compared to an oil fired system. Additionally, from the perspective of behavior it can be intuitively argued that people may be more comfortable in conventional technologies and may opt to install a gas fired boiler when their oil fired boiler comes to an end of its life. Addressing two aspects can make a difference here. First an increased upfront grant amount from the government in the form of different support mechanisms to take care of the higher capital investment required for a biomass system. However as was evident from the results, the policies need to ensure that the pellets are sourced from waste wood so that the GHG savings are the maximum. Secondly, awareness campaigns to spread the information that a biomass system can be more economical over its lifetime compared to the available alternative option.

5.2 Scenario 2: District heating using a wood-chip fired boiler for base load

5.2.1 The Process Chain

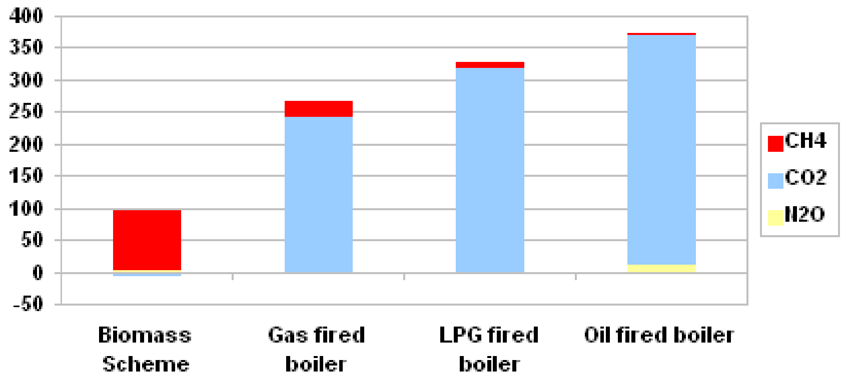
Unlike Scenario 1, this scenario considers a wood chip fired biomass boiler. The wood chips are generated from forestry residues from the UK. The process chain hence starts from the regeneration and harvesting of the forestry residues and ends with the provision of heat at the community along with the disposal of the ash and includes the many associated sub-stages related to these as well. We consider the disposal of the ash here because of the much higher quantity of ash that will be generated in this scheme involving the district heating for 100 households. In this scenario we do not consider the reference case that the source of the wood chips was destined for a landfill. This is to make the scenario more realistic because for such a scheme involving district heating for 100 households it requires dedicated source of forestry residues which will be a valuable traded product. The installation of a gas fired boiler for instances of peak load is included in the economic calculations.

5.2.2 Environmental Assessment

The environmental assessment once again consisted of two parameters: namely the net GHG emissions and the net primary energy from fossil fuels required to generate a MWh of heat from the different systems considered.

It was found that the use of wood chips from forestry residues can save 175.7 kg CO_2 per MWh of heat generated in comparison to the same amount of heat generated from a gas fired plant.

Considering our case where the district heating system would have been equipped solely with a natural gas fired boiler if the biomass boiler is not considered, we see that the emissions from a gas fired boiler are about thrice the emissions from the wood chip fired biomass boiler (Figure 5-5) thereby giving us roughly up to around 65 % lesser GHG emissions. We do not calculate and account for the emissions from the 600 kW gas fired boiler here, however, that would not have affected the GHG savings and they would have remained unchanged.



Source:	CO2	CH4	N2O	Total:	Range:
		kg CO2 eq/MWh			+/-
Biomass Scheme	-4.1	92.5	5.8	94.2	1.7
Gas fired boiler	242.0	25.3	2.6	269.9	
LPG fired boiler	318.9	8.6	2.6	330.1	
Oil fired boiler	359.8	1.9	13.5	375.2	

Figure 5-5: Comparison of GHG's emitted in kg CO_2 equivalent per MWh of heat generated in case of a wood-chip fired biomass and other fossil fuel boilers for the district heating system.

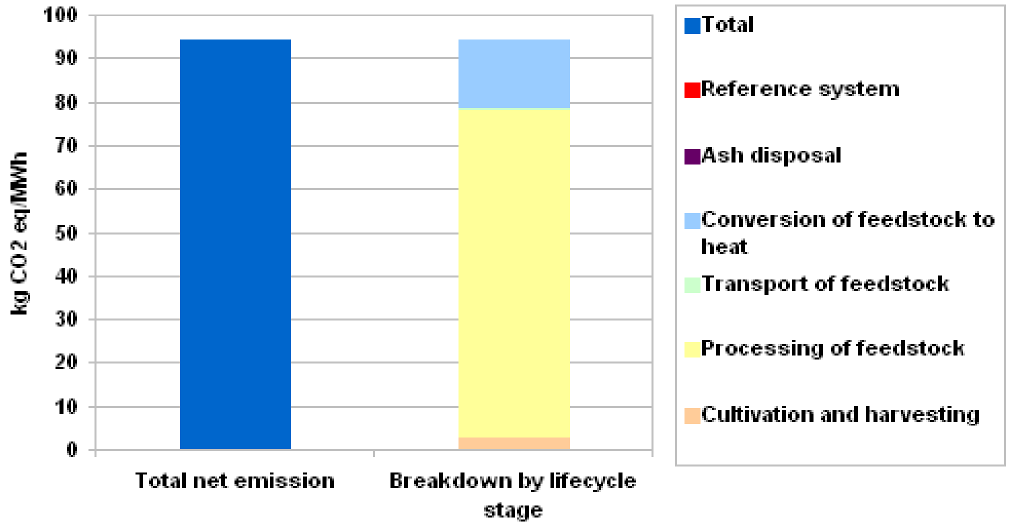
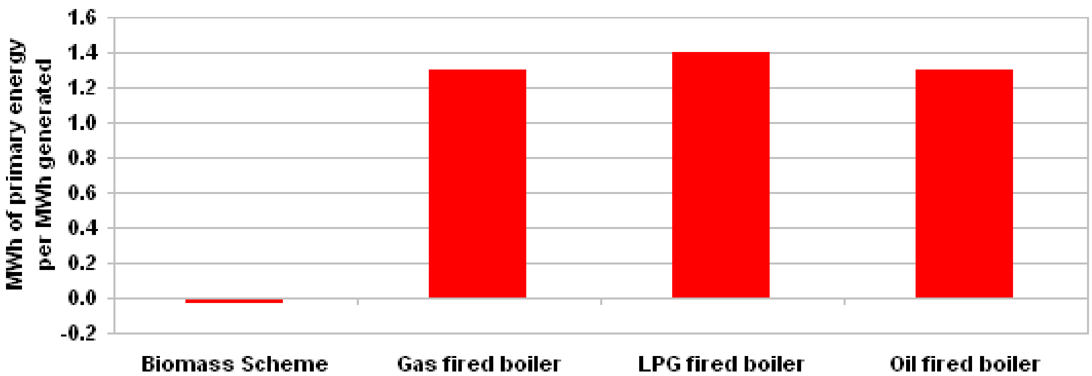


Figure 5-6: Graphical breakdown of the GHG's emitted (kg CO_2 equivalent per MWh of heat generated) in the case of a wood-chip fired biomass across different stages in its life cycle.

Table 5-3: Actual breakdown of the GHG emissions in kg CO_2 equivalent per MWh of heat generated in case of a pellet fired biomass boiler across different stages in its life cycle.

Activity	CO_2	CH_4	N_2O	Total GHG	Primary energy required MWh/MWh
Conversion of feedstock to heat	8.3	1.4	5.9	15.6	0.1
Ash disposal	0.0	0.0	0.0	0.0	0.0
Cultivation and harvesting	2.8	0.0	0.0	2.8	0.0
Processing of feedstock	-15.8	91.1	-0.1	75.2	-0.1
Transport of feedstock	0.5	0.0	0.0	0.6	0.0
Reference system	0.0	0.0	0.0	0.0	0.0
TOTAL	-4.1	92.5	5.8	94.2	0.0

The emissions result mainly from the processing of the feedstock as can be seen from Figure 5-6. In it the biogenic emission of CH_4 from the landfill site upon the disposal of the wastes from chipping make up the single largest source of emissions as can be seen from Figure 5-3. The remainder of the emissions result mostly from the combustion of the wood chips for heat (Figure 5-6 and Table 5-3). The negative values for CO_2 and N_2O seen in Table 5-3 for the processing of the feedstock result from the energy recovered in the form of electricity from the disposal of the chipping wastes to landfill. This electricity then displaces the grid electricity thereby mitigating emissions for which we get a credit. This brings down the primary energy consumed for the generation of a MWh of heat for the biomass boiler (as seen in Table 5-3) by offsetting the amount of primary energy associated with the amount of electricity generated from the landfill. In fact, for the biomass boiler the primary energy consumed per MWh of heat produced is 0.0 MWh. This leads to significant gains in terms of the primary energy consumed per MWh of heat in comparison to the other fossil fuel fired boilers (Figure 5-7).



Source:	Primary energy MWh per MWh:
Biomass Scheme	0.0
Gas fired boiler	1.3
LPG fired boiler	1.4
Oil fired boiler	1.3

Figure 5-7: Comparison of primary fossil fuel used per MWh of heat produced by the wood-chip fired biomass boiler and other fossil fuel fired boilers.

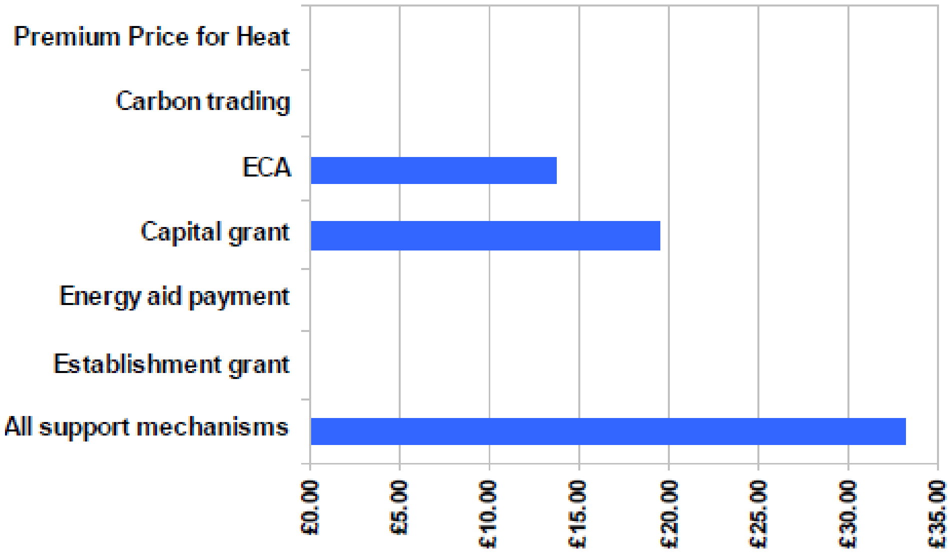
5.2.3 Economic Assessment

Similar to Scenario 1, the cost of heat generated from the biomass boiler was calculated using a lifetime of 25 years, a discount rate of 5% and a cost of capital of 10%. Table 5-4 shows that the price of heat generated from the biomass scheme is lower at £36.22/MWh than the corresponding price of heat generated from an oil fired boiler at £40/MWh. When the existing financial support mechanisms of Enhanced Capital Allowance and the Capital Grant were considered, it brought down the price further to £26.54/MWh. However these numbers are reflective of the price of heat generated solely from the biomass boiler. Since in this scenario we install a gas-fired boiler as well to meet the total energy requirement for the community, the price of heat generation for the entire system was determined separately replicating the method used in $BEAT_2$ for the biomass boiler. It included in addition to the costs associated with the biomass boiler, the costs of installation, operation and maintenance of the gas fired boiler which will be necessary to meet the total heat requirement of the community. These have been presented in Table 5-4 as well. We see that without any support mechanism, the average price per MWh of heat generated by the combination of the wood-chip boiler and a natural gas fired boiler is £35.62 while on consideration of the existing support only for the biomass boiler; the price reduces to £28.83. The price difference was influenced by the relative proportion of the heat energy requirement met by the wood-chip boiler and by the natural gas boiler. In this scenario the biomass boiler generates about 1200 MWh and the gas boiler about 500MWh heat of the total requirement of a 1700 MWh ca as described initially in the Scenario 2 description.

Table 5-4: Price of heat production from the wood-chip fired biomass boiler (Scenario 2) with and without support mechanisms and from the combination of the biomass and the gas boiler. The indicative price of heat from an oil fired boiler has been shown as well.

Support Parameter	Heat price for the wood-chip boiler's contribution only (£/MWh heat)	Heat price for the total heat energy generation (Wood-chip + Natural Gas) (£/MWh heat)
No support mechanisms	36.22	35.62
Currently available support	26.54	28.83

Indicative price of heat from an oil fired boiler (exc duty) is £40.00/MWh



All support mechanisms	£33.14
Establishment grant	£0.00
Energy aid payment	£0.00
Capital grant	£19.50
ECA	£13.65
Carbon trading	£0.00
Premium Price for Heat	£0.00

Figure 5-8: Cost of support mechanisms per tonne of CO_2 saved in Scenario 1. The savings have been calculated in comparison to a small oil fired boiler.

As with Scenario 1, we see that the biomass option is cheaper over the lifetime of the plant considering all costs involved. Figure 5-8 charts the cost incurred by the support mechanisms per tonne of CO_2 in comparison to an oil fired boiler and we see it to stand at £33.14. The value of support increases to £53.02 per tonne of CO_2 compared to the savings with respect to a gas fired boiler as a result of a decrease in the margin of savings.

We have seen in both the scenarios that the price of heat generation from biomass fired systems or a combination of a biomass and a fossil fuel fired system is cheaper than the other alternative considered. However as mentioned before this may not be enough to encourage people to make the switch. Further reduction in the price of heat generated from biomass systems can be expected with the support mechanisms currently in the pipeline. A fundamental manner in which the two scenarios differ however is that in Scenario 1 while the householder makes the initial investment and pockets the subsequent ongoing costs as well, in the latter scenario, it is the builder that puts the initial investment for building the district heating system and the householders only support the operating and maintenance cost. For instance in Scenario 1, the cost of installation of the 20kW_{th} biomass boiler in the domestic household was £5000 and the cost of the wood pellets was £883 per year. The initial capital cost however came down to £3,500 with the help of the capital grant. A comparative oil fired boiler would have cost approximately £1600 and about £1420 in fuel costs. In either case it was the household which had to take care of these costs and it can be expected that if the difference in the upfront cost can be reduced, more households will opt for a biomass based system. However, for Scenario 2, it is the builder that puts in the initial cost of £345,000 ca. (£169,050 ca. with support mechanisms) for the biomass boiler and £48,000 ca. for the gas fired boiler whereas households share the cost of the wood-chips and gas which comes to £33,566 ca. per annum for the 100 households. A gas fired boiler for the whole district heating system would have cost the builder about £140,000 ca. with an annual fuel cost of £35,805 ca. Thus, in this scenario we see that the builders do not directly benefit from the investment and hence may not go for a biomass based district heating system. Here policies imposing obligations as well as providing incentives to the builders will be crucial in determining whether the biomass option is opted for.

Chapter 6

Conclusion

From the two very realistic scenarios which were evaluated to examine the current UK policies to support biomass based heating systems we conclude the following:

- Hypothesis 1 which stated that the existing support mechanisms provide a net economic benefit per MWh of heat generated holds its ground. However it was seen that although the support mechanisms brought down further the price per MWh of heat generated, it was already less that the indicative price of heat generated using an oil fired boiler.

- Hypothesis 2 on positive net GHG savings in comparison to fossil fuel based heating options stands validated too. However this will be the case only when good practice is ensured. Net GHG savings result only when wood pellets (Scenario 1) are made from waste wood and not virgin wood. If virgin wood is used, the option leads to slightly more GHG emissions than a comparable gas fired boiler, however the use of waste wood leads to significant GHG mitigation potential. In the case of the district heating (Scenario 2) the use of forestry residues sourced from forests in the UK has the potential to significantly contribute to GHG reduction since it was seen that the heat if generated using fossil fuel based boilers would lead to significantly more GHG emissions. It was also proven that the value of the support mechanisms per tonne of CO_2 saved for the wood-pellet based heating system is significantly less than its currently traded value even at a time when the EU ETS CO_2 trading price per kg has gone down significantly. However for the district heating installation (Scenario 2) we found this to be incorrect since the value of the support mechanisms exceeded the traded value of CO_2.

The current level of support existing in the UK for households exists mainly in the form of Bio-energy Capital Grants (England) and the Low Carbon Buildings Programme (UK wide). In addition to this households get a reduced rate of VAT as well be eligible for zero stamp duty if they can make their home carbon neutral. One of the key barriers identified for biomass based heating system for households was the greater upfront cost. More support in the form of grants to lower this initial burden to households is expected to make a significant difference. It was seen that there was more room for financial incentives to encourage people to opt for a waste-wood sourced wood-pellet based biomass heating system since there is a huge difference between the value of support mechanisms for a tonne of CO_2 abated and its traded value in the EU ETS. The two sectors although not integrated at the moment since the EU ETS covers only installations greater than 20MW, it is informative to note the large difference observed. If for a moment we consider some form of integration, firms in the EU ETS sector can invest in here to make it more economical for them to meet their targets. This while still reducing the GHG emissions will make the process more economical for them as well as the householders. The CERT scheme can be helpful here if the energy suppliers are indeed able to encourage householders to opt for low carbon measures as per its statutory obligation.

In terms of the support of district heating systems the case was found to be much diverse. In case the district heating system is installed by an energy supplier, mechanisms like LCBP, CERT, and the RHI will be applicable it can draw the incentives from these programs by meeting the requirements or obligations. For district heating systems, the key barrier identified was that the developer does not gain much from the investment in the scenario we considered. The zero stamp duty may be useful here in offsetting costs for the developers if they are able to make the DH system count towards making the house carbon neutral. However, the use of non-financial based policy mechanisms can also be instrumental in determining the level of expansion of biomass based heating. Changing the procurement policies of public institutions as well as promoting options like district based heating systems will make a difference. The success of non-financial based policy was demonstrated in Denmark by the legislation enforcing district heating and within the UK in a much smaller scale with the Merton ruling. In addition to these measures the upcoming and open consultations in the UK which include proposals to promote district heating in suitable communities are the HES and the CESP. These have the potential to further facilitate the expansion of biomass based district heating systems in the UK.

Chapter 7

Recommendations and Limitations

In view of the results obtained from the two scenarios the following measures are recommended:

- Support mechanisms need to clearly reflect the condition that if biomass based heating for individual households are pellet based the source of the material for the pellets are from waste wood.
- It is recommended that for domestic householders the value of support mechanisms for biomass systems be established so that it is high enough to encourage a switch by considerably easing the burden of the initial capital costs. At the same time it should be adjusted so that the value of support per tonne of CO_2 saved in this sector is below the price at which it is traded in the EU ETS sector so that the entire process makes economic sense if an attempt is made to integrate the two sectors at some level.
- For district heating systems exploration of non-financial policy options is strongly recommended.

The following limitations of the study were identified:

- Although a focus is made on the expansion of biomass heating in the UK, we do not determine how much of the expansion will be sustainably feasible and acceptable and how to ensure that the policy mechanisms are able to reach that level of expansion and not overshoot.
- The idea of integrating the EU ETS and the non EU ETS sectors for price comparison although referred to, is not investigated further.

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Appendix A - Parameters used in Scenario 1

Table A- 1: Values of the different $BEAT_2$ parameters used in Scenario 1

Parameter	Assumption/Value
Net thermal efficiency of boiler	90%
Size of plant (thermal input rating)	20kWt
Lifetime of boiler	25 yrs
% energy used during start up and feed	1.6%
Reference round trip distance for disposal to landfill with waste recovery	50km
Description of Site Location	Rural/Isolated
Description of Site Access	average
Ash content of dry wood	0.5% by wt.
Moisture content of waste wood chunks at source	50% by wt.
Include reference system (disposal to landfill with energy recovery)	yes
Drying system	bulk
Days in storage	28
Moisture content of stored wood after drying	7% by wt.
Losses during chipping	2%
Losses during drying and storage	0.5%
Losses during milling	2%
Losses during pelletization	2%
Include disposal to landfill (with energy recovery) of losses from chipping	no
Round trip distance for disposal of losses from waste wood chipping	0
Average round trip distance - From sawmill or factory to processing (chipping, drying and pelleting) (Stage 1)	50km
Losses - From sawmill or factory to processing (chipping and drying) (Stage 1)	1%
Average round trip distance - From processing (chipping and drying) to CHP plant (Stage 1)	100
Annual load factor (Boiler)	18
Losses - Transport from pelleting and storage site to power plant	1%
Cost of Boiler	£150/kWt
Round trip distance for ash disposal	0km

Table A-1 contd.

Parameter	Assumption/Value
Allow ash displacing application of lime to land	no
Capital cost	£250000/MWth
Cost of Feedstock	£140/odt
Annual operating and maintenance costs	£250
Discount Rate	5%
Enhanced Capital Allowance	0
Premium price for biomass heat	0
Carbon trading	£0/t CO_2
Capital grant	30% of capital costs
Ash disposal costs	£0/tonne
Insurance Costs (annual)	0.25% of capital costs
CO_2 savings to be calculated in comparison to…	Small gas fired boiler
Cost of capital	10%

Appendix B – Parameters used in Scenario 2

Table B- 1: Values of the different $BEAT_2$ parameters used in Scenario 2

Parameter	Assumption/Value
Size of plant (thermal input rating)	0.69MWth
Net thermal efficiency of boiler	80%
Description of Site Location	urban
Include high temperature drying?	no
Seedling planting rate	29per ha.a
Description of Site Access	good
Average annual yield (total biomass)	6.75ar t/ha per year
Moisture content on harvest	50%
Ash content of stored wood	0.4% by wt (odt)
Fertilizer application during establishment	0 kgN/ha
Include reference system for waste wood from saw log processing (disposal to landfill with energy recovery)	no
Reference round trip distance for disposal to landfill with waste recovery	0km
Dryig system	bulk
Days in storage	180
Moisture content of stored wood after drying	25
Round trip distance for disposal of losses from waste wood chipping	0km
Losses during drying and storage	0km
Price of waste wood and needles	£0/tonne
Price of harvested branchwood	£7/tonne
Price of small roundwood	£15/tonne
Price of saw logs	£30/tonne
Transport mode - Transport of branchwood to chipping plant	road
Average round trip distance - Transport of branchwood to chipping plant	1km
Transport mode - Transport of branchwood chips to storage	road
Average round trip distance - Transport of branchwood chips to storage	20km
Annual load factor of the boiler	65
Lifetime of plant	25 yrs
Transport mode - Transport of waste wood chunks to chipping plant	road
Average round trip distance - Transport of waste wood chunks to chipping plant	1km

Table B-1 contd.

Parameter	Assumption/Value
% of energy used for start up and feed	1.1%
Transport mode - Transport of waste wood chips to storage	road
Average round trip distance - Transport of waste wood chips to storage	20km
Cost of boiler	150/MWt input
Transport mode - Transport of chips from storage to heating plant	road
Round trip distance for ash disposal	20km
Average round trip distance - Transport of all chops from storage to heating plant	0km
Allow for ash displacing application of lime to land	yes
Losses - Transport of all chips from storage to heating plant	1%
Capital cost	£500000/MWth
Cost of Feedstock	£65/odt
Annual operating and maintenance costs	£17500/year
Ash disposal costs	£0/tonne
Insurance Costs (annual)	0.25% of capital costs
Discount rate	5%
Capital grant	30% of capital costs
Enhanced Capital Allowance	21% of capital cost
Premium price for biomass heat	£0/MWh heat
Carbon trading	£0/t CO_2
CO_2 savings to be calculated in comparison to	Gas fired boiler
Cost of Capital	10%