Project Acronym: SERVE
REF EC: (Project Number) TREN07/FP6EN/S.07.71106/038382
REF (project coordinator org.):
DOCUMENT: Economic benefits of biomass CHP
REF.: Deliverable 7.2d

Project Coordinator: Seamus Hoyne
Project coordination org.: Tipperary Rural and Business Development Institute
Date: 23 April 2010
Revision: 1.0

Deliverable Report
Deliverable No.: 7.2d
Work Package No: 7

CONCERTO INITIATIVE
SERVE

Sustainable Energy for the Rural Village Environment

Report Title:

Economic Benefits of Biomass CHP

Date: 23 April 2010

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Version: 1.0

CONCERTO is co-funded by the European Commission

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1 Introduction

Work package 7 within the SERVE Project focuses on specific research related to sustainable electricity supply. The main objective of this research is to investigate and make recommendations which will lead to the implementation of methods and technologies to achieve sustainable electricity supplies within the Eco-village, in particular, and also in the wider SERVE Region. The activities include:

a) Community Purchasing of Energy (SERVE Region)
b) Local grid development and control (Eco-Village)
c) Future on-site renewable electricity supply options (Eco-Village)

Work has been progressed on the third objective with the production of this deliverable report which forms Deliverable 7.2d. The technical details are attached in Appendix 1, which provides a comprehensive cost benefit analysis of installing a biomass combined heat and power (CHP) scheme in the utility area of the Eco-Village. This report has been produced by Senergy Econnect. It outlines the state of the small scale CHP market and identifies three potential units that may be suitable for installation at the Eco-Village. Three scenarios have been defined and the cost benefit analysis has been carried out for a number of market conditions, ranging from the current cost of electricity and biomass fuel to potential future conditions where these costs may be higher or lower depending on economic developments. The report concludes that under current condition the existing biomass boilers are the best economic solution, and indicates clearly the future conditions under which biomass CHP may become economically viable.

2 Appendix 1: Economic Benefits of Biomass CHP

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Tipperary Institute – SERVE

D7.2d: Report on Economic Benefits of Biomass CHP

Senergy Econnect project number: 2061

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Document History		
Issue No	**Description**	**Date**
01	Original Document Issue	23 Apr 2010

Executive Summary

The Tipperary Institute (SERVE project leader) commissioned Senergy Econnect to undertake a cost benefit analysis for installing biomass combined heat and power (CHP) technology at the Cloughjordan Ecovillage. This study included taking into account both the existing Renewable Energy Feed-in Tariff (REFIT) and its proposed upgrade to REFIT II, and carrying out a sensitivity analysis based on potential future costs of electricity and biomass (woodchip) fuel.

Senergy Econnect undertook extensive international market research which led to the identification of three potentially suitable biomass CHP units. Taking into account the thermal and electrical power ratings of these units, three scenarios were formulated for analysis, along with a baseline scenario which assumed no changes to the current system. The analysis found that:

- Under current economic and market conditions, where the cost of electricity is 12c/kWh and the cost of biomass fuel is €110/tonne, it is not economical to pursue any of the three biomass CHP scenarios analysed.
- The introduction of the REFIT II framework will improve the economic viability of biomass CHP, but only for biomass CHP schemes that have enough electrical generation capacity to both offset the site load and export to the grid. Should other economic parameters remain unchanged, then it is still unlikely that it would be economical to install biomass CHP instead of or in addition to biomass boilers.
- Increasing electricity costs and decreasing biomass fuel costs will improve the economic viability of biomass CHP over biomass boilers. For biomass CHP to be economically viable under the current REFIT framework, the cost of electricity would have to be greater than 17c/kWh, or the cost of biomass fuel would have to be less than €30/tonne. For biomass CHP to be economically viable under the proposed REFIT II framework, the cost of electricity would have to be greater than 17c/kWh, or the cost of biomass fuel would have to be less than €70/tonne.
- In the event that a very cheap or free biomass fuel source can be secured, such as waste wood from a timber merchant, biomass CHP may be economically beneficial, even under the existing REFIT framework and with current electricity costs. If the biomass fuel source is free, it is economical to pursue biomass CHP providing that the cost of electricity is greater than 10c/kWh under the existing REFIT framework, and greater than 4c/kWh under the proposed REFIT II framework.

Other factors that may improve the future viability of biomass CHP include the introduction in Ireland of a scheme similar to the Renewable Heat Incentive currently under consultation in the UK, which may offer an additional revenue stream for the thermal energy generated by biomass CHP projects. The development and growth of the small scale biomass CHP market with an increase in the number, efficiency and value of its products would also improve the economic case.

The Ecovillage does not plan at present to replace its current biomass boilers with biomass CHP units for at least a period of two years; the REFIT II framework is expected to be in place within that timeframe. However, even assuming that the REFIT II framework is in place, notable changes in both the cost of biomass fuel and electricity would be required for a biomass CHP scheme to become economically viable. Whilst these changes are possible, assuming that no major event takes place to change economic conditions drastically, it does not seem likely that a biomass CHP option would provide good economic value when compared to the existing biomass boilers.

Senergy Econnect has built a range of models and these could be re-run at a later date should the Ecovillage wish to revisit the economic case for biomass CHP.

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1 Introduction

Sustainable Projects Ireland Ltd (SPIL) is currently developing the Cloughjordan Ecovillage, a low carbon village development in County Tipperary, Ireland, that will consist of 132 dwellings and 3 community buildings. The Tipperary Institute is working with SPIL to investigate sustainable energy sources for the development, under the European Union (EU) funded project "Sustainable Energy for the Renewable Village Environment" (SERVE). As part of this work, the Tipperary Institute has commissioned its partner Senergy Econnect Ltd to undertake an economic assessment of biomass (woodchip) combined heat and power (CHP) units for the Ecovillage.

The Ecovillage is currently under construction, with an estimated 20 dwellings due to be completed by spring 2010. A district heating (DH) system and other utility infrastructure have already been installed. Two 500kW biomass fired boilers, to supply the thermal load of the development via the DH system, have also been installed and a 500m^2 solar thermal array has been included in the design and is due to be installed in 2010. The Cloughjordan Ecovillage Service Company Ltd (CESCL) will act as the residential estate manager, and so will administer the boilers, solar array, and DH infrastructure. CESCL is a separate entity to SPIL.

This report investigates the economic case for installing biomass CHP instead of and in addition to the existing biomass boilers. The thermal output from the biomass CHP would supply the thermal load of the development (as the current boilers do) and the electrical output would be used to power the plant equipment of the Ecovillage utility area, with any excess electricity exported to the grid. The potential savings from electrical energy offset for the plant equipment, and revenue from the exported electrical energy are key considerations in the economic analysis.

This report details the existing and planned Ecovillage infrastructure in Section 2, the capital and operational economics of the current heating system in Section 3, an overview of the biomass CHP market with potentially suitable technologies in Section 4, before setting out the assessment methodology in Section 6 and results from the financial analysis in Sections 7 and 8.

1.1 Nomenclature

Ø - Diameter

CAPEX - Capital Expenditure
CESCL - Cloughjordan Ecovillage Service Company Ltd
CHP - Combined Heat and Power
DH - District Heating
EU - European Union
NPV - Net Present Value
OHC - Operational Heat Cost
OPEX - Operational Expenditure
ORC - Organic Rankine Cycle
REFIT - Renewable Energy Feed-in Tariff
RHI - Renewable Heat Incentive
RO - Renewables Obligation
SERVE - Sustainable Energy for the Renewable Village Environment
SPIL - Sustainable Projects Ireland Ltd
Syngas - Synthetic gas
THC - Total Heat Cost
VAT - Value Added Tax
WTG - Wind Turbine Generator

2 Existing Ecovillage Infrastructure

2.1 Thermal Energy Generation and Supply

SPIL are required as developers to install utility services for the site plot owners, although the operation of the infrastructure will eventually pass to CESCL. To this end SPIL have planned a heating system that consists of:

- 2 x 500kW Herz biomass boilers (installed and operational)
- 500m^2 solar thermal array (due to be operational April 2010)
- 20,000litre hot water buffer tank
- DH system (installed and operational)
- House stations (installed with each dwelling)

The total cost for the above system is circa €1,285,000 [1].

The two biomass boilers and 20,000litre buffer tank are installed in the Energy Centre building, along with three storage bays for up to approximately 90tonnes of woodchips, and a 3-phase electrical distribution board for the Energy Centre plant. Planning permission for the Energy Centre was received in September 2008.

The 20,000litre buffer tank was installed to maximise the use of solar energy during the summer months and ensure the biomass boilers operated at maximum efficiency during the winter months. The biomass boilers directly heat water in the top third of the tank and the solar thermal array heats water in the bottom two thirds. However, during times of high solar irradiation the solar thermal array may also heat the top third of the buffer tank.

The DH infrastructure is responsible for transporting the thermal energy, via the medium of water, from the boilers and solar generation to the residential plots and community buildings. It consists of a total of 2.5km of piping, the core 700m of which is Ø100mm piping with the rest consisting of Ø60mm and Ø40mm piping. The DH system includes two pumps to circulate the water around the system, both with variable speed capability. One pump is sized for peak load, with another smaller pump sized for summer load. The system pressure is maintained between 1.5bar and 2.0bar by a pressurisation unit. The total installed cost for the DH infrastructure is circa €275,000 [2].

Each dwelling in the Ecovillage will have a hot water storage tank of 800litres, plate heat exchanger, and metering unit, which are installed as standard by SPIL. The 800litre tanks are not directly connected to the main DH system, but the thermal energy is supplied to each house via the plate heat exchanger and regulated by a graduated valve.

The Biocontrol 3000 system is used to control the whole heating system, which includes the two boilers, solar thermal array, 20,000litre buffer tank, and the DH pump management. The control unit can be remotely monitored on a PC via a modem connection.

2.1.1 Biomass Boilers

The two boilers are Herz BioMatic 500 Biocontrol Boilers with a variable power output rating of 79-500kW, giving a total installed capacity of 1MW [3]. The biomass fuel source is woodchips with 35% moisture content, but wood pellets can also be used. Figure 1 is a cut-through diagram which details the internal layout of the boilers (please refer to Appendix A for the diagram key).

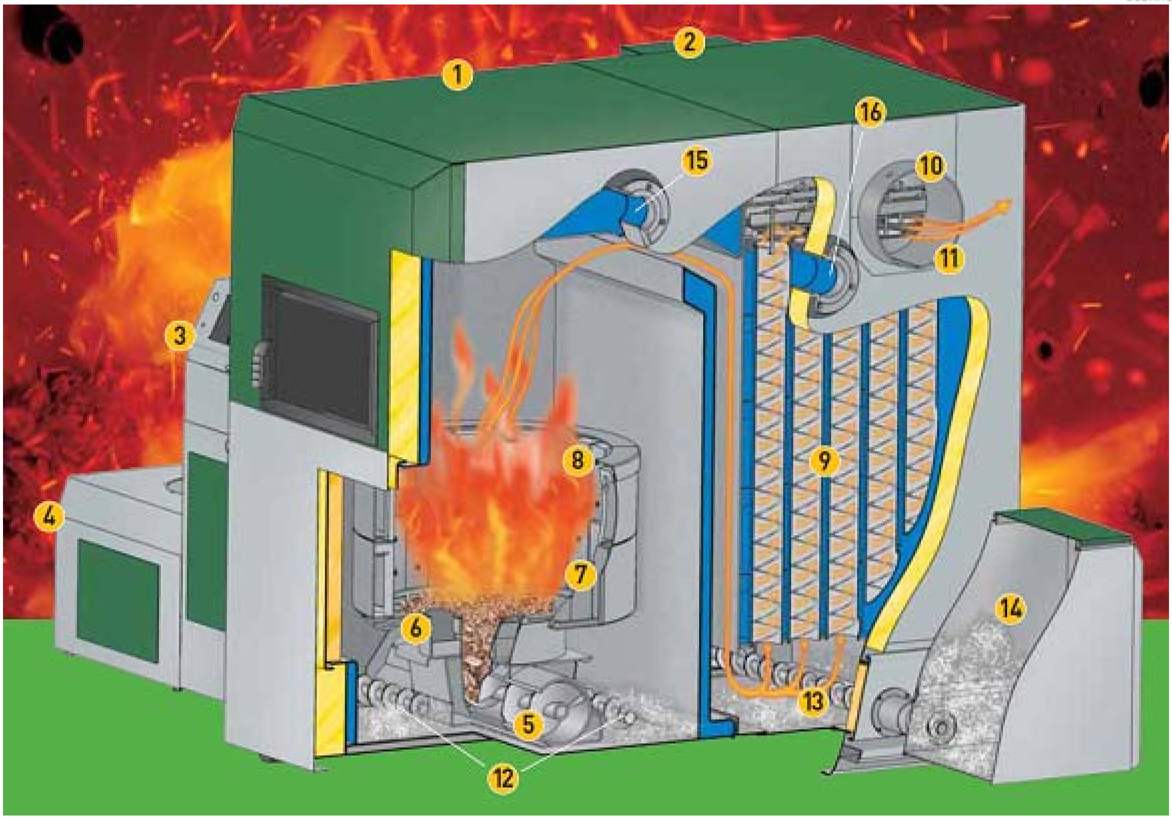

Figure 1: Herz BioMatic Boiler Diagram

The two boilers work on a "lead" basis, with one boiler as the lead boiler and the other boiler as the secondary boiler. The secondary boiler only fires on when the load exceeds 500kW or there is a failure with the lead boiler. The boilers switch lead and secondary roles every 200hours in order to roughly apportion the run hours and associated wear of the boilers. The lead boiler is expected to be firing for approximately 90% of the time, although this may be reduced during periods of high solar irradiation or low thermal load from the Ecovillage.

At full power output (500kW) each boiler consumes approximately 500kg/hour of biomass. The boiler can be fuelled with biomass with up to 30-40% moisture content. The boilers have an expected lifetime of 12-15years [4].

2.1.2 Solar Thermal Panels

The initial plan for a solar thermal array of approximately 530m^2 was modified to an area of 506m^2, for which planning permission was received in September 2008. The solar thermal array will supply thermal energy to the 20,000litre buffer tank via a heat exchanger. During normal operation the solar thermal array will heat up the bottom two thirds of the buffer tank, and during periods of high solar irradiation it will also heat up the remaining top third. This energy will then be distributed through the DH system as required.

The solar thermal array will be made up from individual flat plate solar panels (approx 12m^2) and is due to be operational in April 2010. The total cost for the solar thermal array, mountings, and pump unit is approximately €227,150 [1].

2.2 Electrical Generation and Supply

In contrast to the central provision of renewable thermal energy via the biomass boilers and DH system, there is currently no centralised electrical generation to supply the 132 dwellings plots with green electricity. Instead the dwellings and community buildings are all grid connected. One obstacle to the development of such an on-site centralised generation scheme is that private electricity networks are not permitted in Ireland, and so any centralised generation could not be supplied directly to the residential dwellings. In effect, the electrical energy would have to be exported onto the grid, at the point of generation, and bought by a supply company under a Power Purchase Agreement, and then purchased back individually by each dwelling. There would be no discernable economic benefit for the residents of the Ecovillage under such a scheme.

However, in line with the ethos of the Ecovillage, it is desirable that the electricity consumed by the Ecovillage is "green". Given that direct supply to all the dwellings from a CESCL operated centralised renewable source is not possible due to the standing of private networks, the following non-mutually exclusive approaches have so far been considered:

1. Green tariff with electricity supply company
2. Community investment in an offsite green electricity generation scheme (e.g. local wind farm)
3. On-site generation

NB. The electrical energy generated from the proposed CHP units would be used to supply the loads within the Energy Centre (e.g. pumps, control equipment etc.) with any excess energy exported to the grid. As stated above, due to the status of private networks in Ireland, this energy cannot be used to directly supply the residential dwellings within the Ecovillage.

2.2.1 Green Electricity Tariff

Ecovillage residents will be encouraged to sign up to an electricity supplier which offers a "green" tariff. SERVE Report D7.1 [5] investigated the supply companies available to the residents (Airtricity, Bord Gáis Energy and ESB Customer Supply) for cost to consumer and "greenness" of the electricity. "Greenness" was assessed by comparing fuel mix and CO_2 emissions factors.

The report found that Bord Gáis Energy was the cheapest of the three suppliers, but only 16% of the electricity supplied was generated from renewable sources. Airtricity was only marginally more expensive, but 79% of the electricity supplied was generated from renewable sources. ESB Customer Supply was the most expensive and only 9% of the electricity supplied came from renewable sources. Based on these findings, Ecovillage residents would be encouraged to sign up with Airtricity for their electricity supply.

2.2.2 Community Investment in a Local Renewable Energy Scheme

Another option under consideration is community investment in a local renewable energy generation project in order to offset the Ecovillage electrical use. It is assumed that the renewable energy project would be generating electricity, e.g. a wind turbine generation (WTG) project, rather than heat, e.g. a solar thermal project.

The details of the investment scheme are not yet finalised, but one approach may be to buy shares in a local renewable energy scheme to a value such that the proportion of electricity generated that can be attributable to the Ecovillage shareholders is greater or equal to the electrical consumption of the Ecovillage. Buying shares in a renewable energy scheme, particularly during the development phase, may also bring financial reward to the shareholders, much like shareholders in a listed company may receive dividends.

A one-off investment sum of €660/dwelling has initially been suggested, giving a total investment portfolio of approximately €87,000 [6].

2.2.3 On-site Electrical Generation

Plans to install a 50kW wind turbine generator (WTG), to supply electrical energy for the loads within the Energy Centre (e.g. pumps, control equipment etc.) with any excess energy exported to the grid, have been considered. The plan has been put on hold due to the expiry of a grant scheme that would have contributed to the project, and because the WTG was not eligible under the new Renewable Energy Feed-in-Tariff (REFIT). Due to the expectation of the introduction of a more generous subsidy scheme for WTG units, SPIL are currently recording wind speed data (planned to commence December 2009) and electrical load data in order to inform the decision making process. A separate report [7] will be prepared to present detail of an on-site WTG installation, assuming no other on-site generation at the Ecovillage.

Clearly if such a scheme were to go ahead, it would have economic implications for the biomass CHP options being presented in this report. The assumption made in this report is that there would not be any other form of on-site generation apart from the biomass CHP. It may be beneficial to investigate the economic cost benefit analysis of the combined effect of an on-site WTG and biomass CHP, and this could be carried out in a separate report under the SERVE project.

3 Baseline Information

3.1 Thermal Loads

The predicted thermal loads that the existing biomass boilers, and so any replacement biomass CHP, must supply are listed in Table 1 (see Appendix B for further information):

	Thermal Load
Minimum Annual Thermal Load	1300MWh/year
Maximum Annual Thermal Load	1860MWh/year
Peak Load	910kW

Table 1: Predicted Thermal Loads

Any replacement biomass CHP or biomass CHP/boiler combination must be able to supply both the maximum annual thermal load of 1860MWh and the peak thermal load of 910kW.

3.2 Capital Expenditure

The total capital expenditure (CAPEX) of the current boilers (including delivery, installation and commissioning), and associated fuel feed systems control unit was approximately €405,150 [1]. This does not include the cost for the pumps as it is assumed that they would be required for any heating system, and will be retained and used for any replacement biomass CHP scenario.

3.3 Annual Operational Expenditure

The predicted annual operating expenditure (OPEX) for the existing biomass boilers is summarised in Table 2 (see Appendix C for further information):

	Cost (€) **Annual Load 1300MWh**	**Cost (€)** **Annual Load 1860MWh**
Biomass Fuel	47,500	68,750
Fixed Costs	24,500	24,500
TOTAL	**72,000**	**93,250**

Table 2: Predicted Annual OPEX

4 Biomass CHP Market Research

CHP generation, also referred to as cogeneration, is the generation of thermal and electrical power from one fuel source. In a conventional power generation system, fuel is burned to power a prime mover which in turn drives a generator. Typically about 65% of the energy contained in the fuel is expelled as waste heat, giving the system an efficiency of only about 35%. CHP systems aim to use this expelled heat, so increasing the total system efficiency to typically 75-85%. This clearly gives the user energy and fuel cost savings.

The act of combining CHP technology with a biomass fuel source is an expanding market, and offers the benefit of an efficient generation system with a renewable fuel source. Whilst many combinations of biomass to electricity conversion technologies are theoretically possible, this report focuses on those combinations which are available on the market and are applicable for a project of this size.

This section of the report gives an overview of the current biomass CHP market, potentially suitable biomass CHP technologies for the Ecovillage project, and the criteria used to select them. Please note that individual suppliers and units used in this report are not specifically recommended by Senergy Econnect, but rather are capable of providing biomass CHP units in the size range that we would be suitable for the projected Ecovillage thermal load. Furthermore, whilst sensible technical aspects have been considered, biomass CHP units identified as potentially being suitable for the Ecovillage have not undergone a formal technical feasibility assessment.

4.1 Overview of Current and Future Biomass CHP Market

A comprehensive analysis of the biomass CHP market was undertaken in order to establish potentially suitable biomass CHP units for the Ecovillage project. In total over 150 companies were researched and assessed on the ability to supply a biomass CHP unit suitable for the Ecovillage, based on the search criteria detailed in Section 4.2. Such a large research pool was required given the lack of established manufacturers in the small scale biomass CHP market, into which the Ecovillage project would fit. The research was not restricted to the UK market, but also considered manufacturers from Europe, North America, Asia, and Australasia.

For market analysis purposes, the biomass CHP market can be broadly split into four categories:

- $<50kW_{th}$ (domestic scale)
- $50kW_{th}$ – $2MW_{th}$ (small scale)
- $2MW_{th}$ – $10MW_{th}$ (mid scale)
- $>10MW_{th}$ (large scale)

The domestic scale has a few biomass CHP offerings, typically from established companies who have traditionally supplied domestic biomass boilers but have branched out into the biomass CHP market. The mid scale biomass CHP market has a number of offerings from established companies (e.g. Caledon Buccleugh) and newer start-up companies. Large scale projects are typically developed on a project-by-project basis by globally established engineering companies or by electrical utilities/suppliers.

The small scale market, into which the Ecovillage project would fit, currently has very few established and respected manufacturers (Turboden perhaps being an exception) or reliable tried and tested products. From the range of manufacturers that do supply this market, very few have a large portfolio of successful case studies (again Turboden being the exception). Many of the mid scale suppliers contacted during the analysis of the biomass CHP market stressed the importance of selecting a manufacturer/technology with successful case studies and working sites, as currently equipment used in the small scale biomass CHP market is prone to technical problems.

The reasons for a lack of established manufacturers operating in the small scale market sector seem to be twofold:

1. Mid scale manufacturers do not scale down their existing technologies for the small scale market as it is not economical to do so. Currently the CAPEX of producing a $1MW_{th}$ biomass CHP is not dissimilar from producing a $3MW_{th}$ plant of the same technology type. Therefore the CAPEX as a proportion of generation capacity (£/MW) increases steeply, thus reducing the economic feasibility of projects of this size. For this reason, established manufacturers such as Caledon Buccleugh do not currently supply biomass CHP projects less than about $3MW_{th}$.
2. Domestic scale biomass CHP technologies are typically based on manual fuel loading and usually require manual cleaning and ash removal. This is clearly not a suitable operation method for projects in the $1MW_{th}$ size range, given the required kg/hour fuel consumption, and the fact that the biomass CHP will be expected to be operated and controlled automatically.

Seamus Hoyne, the manager for the SERVE project, has indicated that any installation of biomass CHP units would be unlikely to take place for at least two years, during which time the small scale biomass CHP market may change for two reasons: economic scaling of technologies already operating successfully in the mid scale market and/or successful development of existing prototype technologies in the small scale market. It is likely that this change will be driven by the existing Renewables Obligation (RO), gas and electricity price increases, and the proposed introduction in 2011 of the Renewable Heat Incentive (RHI), which should financially incentivise the market.

4.2 Biomass CHP Search Criteria

When identifying suitable biomass CHP units for the Ecovillage, it was considered that any potential unit had to comply with the following criteria:

- The unit had to be able to be fuelled with a biomass source of woodchips with 35% moisture content.
- Biomass CHP technologies/units under development were not considered given the associated uncertainties surrounding supply and reliability. Any biomass CHP unit considered had to be available for purchase at time of undertaking the research. Existing case studies of the unit in successful operation was also preferable.
- Gasification units coupled with internal combustion engines were not considered (see Section 4.2.1).

It was also considered that any potential unit should comply with the following criteria:

- A maximum unit generation capacity of $1MW_{th}$ was preferable. It was not considered economical, efficient or in the ethos of the Ecovillage to have a larger unit than was required to meet the $910kW_{th}$ peak load.
- A minimum unit generation capacity of $250kW_{th}$ was preferable. When considering the replacement of one of the existing biomass boilers, it was not considered economical to consider multiple smaller units when one or two larger units would suffice. However biomass CHP units which could be modulated during normal operation to produce less the $250kW_{th}$ were included.
- A maximum unit generation capacity of $150kW_{e}$ was preferable, due to an assumed constant electrical base load at the Energy Centre of $35kW_{e}$ and a known grid connection import capacity of $50kW_{e}$. It was assumed that this 50kW grid connection capacity was reversible (i.e. the existing electrical infrastructure had reverse power capability) and could be increased by a sensible amount.

The fundamental approach when considering biomass CHP units was that supplying the thermal load is the driver and electrical generation is the secondary function.

4.2.1 Gasification

Gasification is an additional stage that can be included in a biomass CHP generating system for converting solid biomass to a methane based synthetic gas (syngas) using a pyrolysis process. Using syngas as a fuel source rather than a solid biomass fuel means that internal combustion engines can be used as the prime mover. These internal combustion engines are usually modified diesel engine/generator designs. When coupled with generators, this set up typically gives a higher electricity to heat ratio than other CHP technologies (can be as high as 2:1 electricity to heat), which may be preferable for some load profiles.

Gasifiers have been around since the first half of the twentieth Century and there are three main designs: updraft, downdraft, and fluidised bed. Whilst recent designs have certainly improved the technology, gasifiers are still dogged by reliability issues, specifically with regard to “clogging” – when the gasifier becomes clogged by the biomass feedstock. In contrast to biomass CHP units that are based on more reliable conventional biomass boilers supplying the thermal energy to a conversion technology (e.g. Stirling engine or Organic Rankine Cycle, ORC), if the gasifier fails then both heat and electricity generating capability are lost; if the Stirling engine or ORC unit break then only the electrical generating capability is lost.

Given ongoing reliability issues, that meeting the thermal load is the primary requirement of any biomass CHP unit for the Ecovillage and so a high electricity to heat ratio is not required, and the low electrical load of the Energy Centre, gasification based CHP technologies were not extensively considered, with the exception of the Stirling DK unit (Section 4.3.2). The Stirling DK was included as it uses an updraft gasifier, which has a lower risk of clogging.

4.3 Biomass CHP Technologies

This section details technologies and manufacturers identified as being potentially suitable for the Ecovillage project.

4.3.1 The Organic Rankine Cycle (ORC)

The ORC is a closed loop thermal to mechanical energy conversion cycle which uses an organic medium with a low boiling point as the working fluid. An organic medium is used as it has a lower boiling point than water and so can use lower temperature heat sources than those required for a steam cycle. The ORC operating cycle can be summarised as follows and each step is illustrated in Figure 2:

1. Thermal energy is supplied to the working fluid in the ORC, which causes the working fluid to vaporise.
2. As the fluid vaporises it expands through a low speed turbine which is coupled to a low speed synchronous generator, so producing electricity.
3. The vapour then enters a condenser where thermal energy is removed by a cooling water circuit, and the vapour condenses back to fluid. This cooling water circuit can then be used to supply this thermal energy for use within a building heating system.
4. The working fluid is pumped back to stage 1 and the cycle is complete.

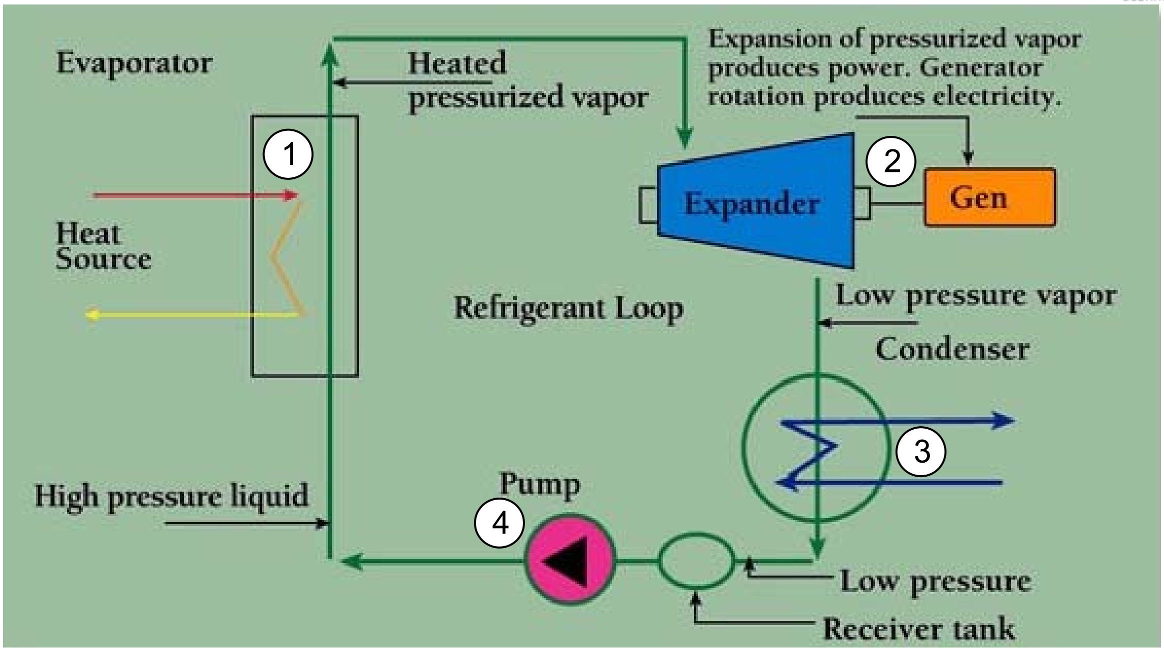

Figure 2: ORC Diagram

In stage 1 above, the thermal energy to the ORC unit can be supplied from a number of sources:

1. a separate thermal oil cycle that is heated in a combustion chamber;
2. flue gas from the boiler, although the thermal energy in modern condensing boilers is quite low; or
3. the hot water out of the boiler, although care needs to be taken to ensure that the water temperature is sufficiently high to boil the working fluid, and still be hot enough afterwards for domestic heating.

ORC units are usually very reliable as they are a sealed system, and have low maintenance requirements as the moving parts (the turbine and synchronous generator) are low speed and often directly coupled through an elastic coupling, negating the need for a gearbox. Turboden is perhaps the market leader in this field, with over 100 installed sites across Europe, but currently the smallest unit they produce is rated at 1844kW$_{th}$ and 400kW$_{e}$, too large for the Ecovillage[1]. ORC units typically have a heat to electricity ratio of approximately 4:1 and efficiencies >95%. However once the thermal energy source is taken into account, the total system efficiency will typically be 75-90%.

One unit which complies with the search criteria (Section 4.2) is a 50kW$_{e}$ unit manufactured by Electratherm and distributed within the UK by Thistle Energy. The efficiency of the Electratherm is stated as being between 10-80% as the efficiency is highly dependant on operating parameters such as the temperature and source of the thermal energy. An efficiency of 50% was assumed for the economic assessment work. One Electratherm unit can be supplied at an approximate cost of £120k, including delivery and site connection. Electratherm do not currently manufacture a larger generation capacity unit.

4.3.2 Stirling Engine

Stirling Engines are external combustion engines that rely on the expansion and contraction of a working fluid, caused respectively by the addition (“heating”) and removal (“cooling”) of thermal energy via a heat exchanger. The expansion and contraction of the working fluid is converted to

[1] At time of research there was market rumour that Turboden were looking to manufacture a 200kW$_{e}$ ORC unit, but Turboden would not respond to queries on this matter.

mechanical energy, usually via a piston and crank shaft arrangement. This rotational mechanical energy can then be converted to electrical energy using a synchronous generator. Stirling engines are sealed units and so can be very reliable and have long operational periods between maintenance requirements.

Like with ORC units, the addition of thermal energy can be supplied from a number of sources. A unit which coupled a Stirling engine directly to a biomass boiler, and so used thermal energy supplied directly from the combustion of the biomass without a gasification stage or thermal oil loop was seen as preferable, but no manufacturers of such a system were found. Instead, Stirling DK manufactures and supplies Stirling engine units which are coupled to updraft gasifiers. The gasifiers produce syngas from the biomass fuel source, which is burned in a combustion chamber and supplies thermal energy to the Stirling engine and water. Figure 3 details such a configuration.

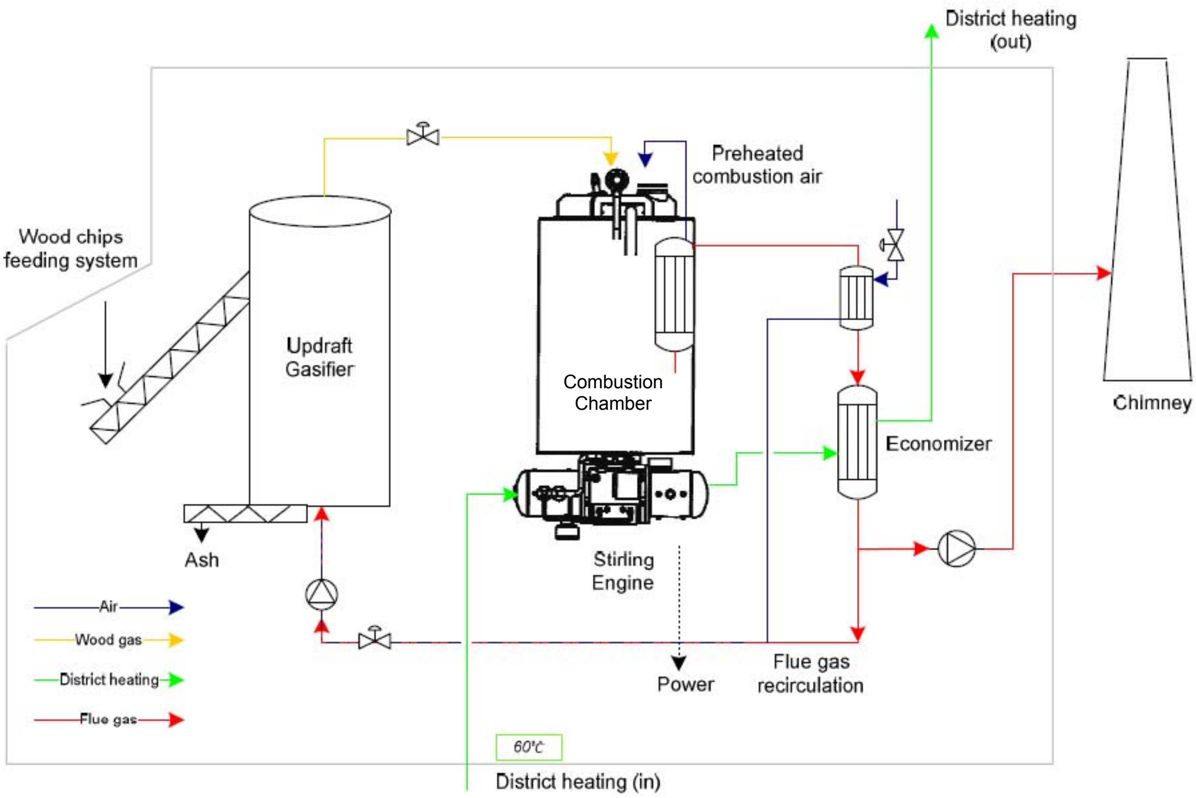

Figure 3: Stirling DK Operating Configuration

The Stirling DK units are modular, and so a range of generation requirements can be catered for. A 420kW$_{th}$ 70kW$_e$ unit has a supply and delivery cost of approximately €480,000.

4.3.3 Talbott's Microturbine

The UK manufacturer Talbott's has developed an open cycle gas turbine biomass CHP unit. Ambient air is drawn into the unit and pressurised and heated, via a heat exchanger, from thermal energy from the biomass combustion chamber. The air then expands through a turbine, which is connected to a synchronous generator, before being fed into a boiler to heat water for domestic heating.

The unit is rated at 100kW$_e$ 200kW$_{th}$. The efficiency of the Talbott's unit is quoted as being over 80%, and one unit can be supplied at an approximate cost of £459k, including delivery and site connection. The unit is self contained in two standard twenty foot equivalent shipping containers, as shown in Figure 4.

Figure 4: Talbott's Biomass CHP Unit

It should be noted that the mk1 version of the Talbott's unit had well publicised reliability problems. However the Talbott's unit was included for analysis in this report as an updated model is currently under testing, which it is claimed addresses the known faults of the mk1 unit.

4.3.4 Steam Boiler with Back Pressure Turbine

Early investigation into this technology gave indicative capital costs >£1m [8]. This, coupled with correspondence with various supplies, indicated that this technology was not suitable for the Ecovillage project, and so did not warrant further investigation.

4.4 Biomass CHP Manufacturer Summary

In summary, based on market research and the selection criteria set out in Section 4.2, the units detailed in Table 3 were identified as being potentially suitable for the Ecovillage project, and so were selected for economic feasibility assessment.

Manufacturer	Technology	Thermal/Electrical Power (kW)	Efficiency	Cost
Electratherm	ORC	0 / 50	50%*	£120,000
Stirling DK	Stirling Engine	420 / 70	83.5%[2]	€480,000
Talbott's	Microturbine	200 / 90**	80%[3]	£459,000

Table 3: Biomass CHP Units for Assessment

*the efficiency can vary from 10-80% depending on a number of operational factors.
**the electrical output is quoted at 80-100kW.

[2] Quotation sent be email 20 March 2010
[3] http://www.talbotts.co.uk/BG1000leaflet.pdf

5 Assessment Scenarios

Based on the generation capacities of the units detailed in Table 3, three possible biomass CHP scenarios were formulated for economic assessment. This section provides information on these three assessment scenarios, and how they might be configured.

It should be noted that these scenarios were identified based on the generation capacities of the units, and no assessment work on the technical feasibility of these scenarios has been undertaken.

5.1 Baseline Scenario

The baseline scenario is an assessment of the current boiler heating system assuming no system changes. The baseline scenario provides a benchmark against which to assess the three biomass CHP scenarios.

5.2 Scenario 1

Scenario 1 is the retrofitting of one 50kW$_e$ Electratherm ORC unit onto the existing Ecovillage heating system, i.e. both existing boilers are retained to provide thermal energy for the Ecovillage and for the Electratherm unit.

It is assumed that the Electratherm unit would be retrofitted onto the existing biomass boiler hot water outlet pipes. The hot water will supply the required thermal energy to the Electratherm evaporator, before it enters the DH network and supplies the Ecovillage. The cooling supply to the Electratherm condenser would be provided by the cool DH return water. This scenario would require the purchase of one Electratherm unit and some minor installation work.

5.3 Scenario 2

Scenario 2 is the replacement of one of the existing biomass boilers with one 420kW$_{th}$ 70kW$_e$ Stirling DK updraft gasifier Stirling engine unit, with the Stirling DK unit acting as the lead, i.e. the remaining biomass boiler would only fire on when the Ecovillage thermal load exceeds the 420kW$_{th}$ that can be supplied by the Stirling DK unit. This scenario would require the sale of one of the existing boilers, the purchase on one Stirling DK unit, and some minor installation work.

5.4 Scenario 3

Scenario 3 is the addition of one 200kW$_{th}$ 100kW$_e$ Talbott's microturbine unit into the existing Ecovillage heating system, with the Talbott's unit acting as the lead, i.e. the existing biomass boilers would only fire on when the Ecovillage thermal load exceeds 200kW$_{th}$.

This scenario will give a total thermal generation capacity of approximately 1.2MW$_{th}$, over 30% greater than the requirement of 910kW$_{th}$. To address this, the replacement of both existing boilers with one 750kW$_{th}$ biomass boiler was considered, but the required expenditure for such a system meant that it was more economical to retain the existing boilers. This scenario would require the purchase of one Talbott's unit and some minor installation work.

6 Assessment Methodology

In order to assess and compare the economic feasibility of the baseline scenario and the three biomass CHP scenarios detailed in Section 5, the following values shall be calculated for each:

1. The Net Present Value (NPV) (Section 6.1). This is the expected lifetime cost of each scenario which takes into account all expenditure and revenue over the project lifetime.
2. The total heat cost (THC) (Section 6.2). This is the cost to supply the expected thermal load over the project lifetime, and takes into account all expenditure and revenue over the project lifetime.
3. The operational heat cost (OHC) (Section 6.3). This is the cost to supply the expected annual thermal load in year 1, and does not take into account the project CAPEX or scrap value of existing boilers.

6.1 Net Present Value (NPV)

The NPV method will be used to compare the relative cost of each scenario and calculate a total project cost (€) after *n* years. This method is commonly used as it takes into account the real-time value of the money. The NPV method converts all annual cash expenditure and revenue over the project into their present values, and then sums them to obtain the NPV:

$$NPV = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} ... + ... \frac{C_n}{(1+r)^n}$$

Where C_0 is the initial CAPEX, C_n is the total loss/profit from year *n* and *r* is the annual interest rate. All scenarios assume a project lifetime of 15 years, and so *n*=15years. A positive NPV indicates capital return (profit). C_n is calculated as:

C_n = Revenue from electricity export and offset – fuel cost – OPEX

where OPEX is the operating cost for year n (i.e. maintenance, insurance etc.). When calculating the total loss/profit for the final year the decommissioning costs and scrap value (the retrievable value from selling the boiler/CHP unit) must be taken into account. For the assessment work, a scrap value equal to 10% of the CAPEX was assumed.

6.2 Total Heat Cost (THC)

The THC is the total average cost (€/MWh) of each MWh of thermal energy generated over the project lifetime, and is calculated by:

$$THC = \frac{NPV}{Annual\,Thermal\,Demand \times Project\,Lifetime}$$

The lower the THC for a scenario, the greater economic value it represents. Given that the annual thermal load is the same regardless of scenario, and a project lifetime value of 15years has been used for all the scenarios, the THC values will be proportional to the NPV values.

6.3 Operational Heat Cost (OHC)

The OHC (€/MWh) is a measure of the annual operational cost required to supply the thermal load, and takes into account the total annual operational expenditure and revenue. It does not take into account the CAPEX or project scrap value. It is calculated by:

$$OHC = \frac{Total\ annual\ OPEX}{Annual\ Thermal\ Demand}$$

The lower the OHC for a scenario, the cheaper it is to operate. It was considered useful to calculate the OHC so that there was some indication of the relative operational costs of running the units.

6.4 Fixed Values

Table 4 details values that were fixed for all scenarios for the economic assessment work.

Parameter	Value
Min Ecovillage Annual Thermal Load	1300 MWh
Max Ecovillage Annual Thermal Load	1860 MWh
Energy Centre Electrical Base Load	$35kW_e$
Biomass Energy Content	3.4 kWh/kg
Biomass Cost	€110/tonne
Value of Offset Electricity	12c/kWh
Value of Exported Electricity	8.4c/kWh
Annual interest rate *r*	3%

Table 4: Economic Assessment Fixed Values

6.5 Assumptions

The following assumptions have been made for the assessment work listed in this report:

- CAPEX and OPEX values are exclusive of Value Added Tax (VAT).
- The exchange rate used throughout the report is £1=€1.1.
- Where applicable, a resale value for the existing boilers of €50,000/boiler was assumed.
- The lifetime of all the equipment has been set at 15 years. Some manufacturers quoted equipment lifetimes in excess of 20years, but given that this is not proven through operation experience, it was considered prudent to use a value of 15 years.
- The maximum thermal load value of 910kW is valid for assumed project lifetime of 15 years.
- Given that the Ecovillage is currently under construction, thermal load will be lower than when all the dwellings are constructed and inhabited. It is assumed for this report that all dwellings will be constructed and inhabited by the time of any biomass CHP installation, and so minimum and maximum annual thermal load values of 1300MWh and 1860MWh

respectively has been used (see Appendix B). The actual annual thermal load can be verified from operational data after full build completion.

- The total annual OPEX for each units are based on manufacturer supplied data and comparison with the predicted annual OPEX for the current boilers. Please refer to Appendix D for details.
- It is assumed that major site installation works will not be required.
- The electrical consumption of the boiler, pumps and biomass CHP units is assumed to be the same for all scenarios, and is included in the constant site base load of $35kW_e$. This can be verified from operational data after full build completion.
- No external funding – the funding of any biomass CHP solution will be met from internal sources.
- For scenario 1, it is assumed that the total annual boiler run hours will be approximately 3715hours and 4650hours for annual thermal loads of 1300MWh and 1860MWh respectively. These values can be verified from operational data after full build completion.
- For scenario 1, it is assumed that the Electratherm will only be able to produce a maximum of $35kW_e$ even though it has a rated output of 50kW. This is based on information from the manufacturer. This can be verified from operational data from actual sites using this unit.
- For scenario 2, based on average thermal load figures of $150kW_{th}$ and $210kW_{th}$ for annual thermal loads of 1300MWh and 1860MWh respectively, it is assumed that the Stirling DK biomass CHP unit will supply 75% of the annual thermal load. This assumption can be verified from operational data after full build completion.
- For scenario 2, it is assumed that the Stirling DK will only be able to produce a maximum of $90kW_e$ even though it has a rated output of 100kW. This is based on information from the manufacturer.
- For scenario 3, based on average thermal load figures of $150kW_{th}$ and $210kW_{th}$ for annual thermal loads of 1300MWh and 1860MWh respectively, it is assumed that the Talbott's biomass CHP unit will supply 60% of the annual thermal load. This assumption can be verified from operational data after full build completion.
- For all scenarios an efficiency of 90% has been assumed for the existing biomass boilers. This can be verified from operational data after full build completion.

7 Analysis and Comparison of Scenarios

7.1 Baseline Scenario

Table 5 details the results from the economic assessment of the baseline scenario. Past CAPEX has not been included, as those costs have already been assigned, and so the baseline scenario has a CAPEX = €0.

	Annual Thermal Load 1300MWh	Annual Thermal Load 1860MWh
CAPEX	€0	€0
Year 1 OPEX	-€71,000	-€91,500
Year 1 Revenue	€0	€0
Total Year 1 Cash flow	-€71,000	-€91,500
NPV	**-€1,011,000**	**€-1,305,000**
OHC	**€55/MWh**	**€49/MWh**
THC	**€52/MWh**	**€47/MWh**

Table 5: Baseline Scenario Assessment

Given that CAPEX = €0, the difference between the OHC and THC values is due to the scrap value of the boilers at the end of the project lifetime. Because of this, the baseline scenario is the only scenario where the OHC>THC.

It should be noted that the assumption of 15 years lifetime for the boilers is the upper limit of what could be realistically expected for the HERZ boilers. Whilst they would still be operational after this time, it is likely that the efficiency would reduce and there could be a safety issue due to degradation of components.

7.2 Scenario 1 – Electratherm Unit

Table 6 details the results from the economic assessment of scenario 1.

	Annual Thermal Load 1300MWh	Annual Thermal Load 1860MWh
Annual CHP Generation	$0kWh_{th}$* $130kWh_{e}$	$0kWh_{th}$* $163kWh_{e}$
CAPEX	€145,000	€145,000
Year 1 Expenditure	-€85,000	-€107,500
Year 1 Revenue	€15,500	€19,500
Total Year 1 Cash flow	-€69,500	-€88,000
NPV	**-€1,142,000**	**-€1,412,000**
OHC	**€53/MWh**	**€47/MWh**
THC	**€59/MWh**	**€51/MWh**

Table 6: Scenario 1 Assessment

*The annual CHP thermal generation is $0kWh_{th}$ as the Electratherm is using thermal energy from the existing boilers to produce electricity, and is not producing thermal energy itself.

Scenario 1 has the lowest CAPEX and THC of scenarios 1, 2 and 3, indicating that economically it represents the best value of the biomass CHP units studied. However the THC of the baseline scenario is lower than scenario 1, indicating that it would not be economically beneficial to install this unit.

For the analysis work a conservative efficiency value of only 50% was used for this unit, given the large stated efficiency range of 10-80%. Analysis was also done using the maximum stated unit efficiency of 80%. This did not change its overall ranking when assessed on OHC or THC, indicating that the low CAPEX rather than revenue from electrical generation make this the economically superior option of scenarios 1, 2 and 3.

To work optimally the Electratherm ORC unit requires a thermal energy source of about 750kW. It is therefore unlikely that an ORC unit with a greater electrical generation capacity would be suitable for the Ecovillage.

7.3 Scenario 2 – Stirling DK Unit

Table 7 details the results from the economic assessment of scenario 2.

	Annual Thermal Load 1300MWh	**Annual Thermal Load 1860MWh**
Annual CHP Generation	$975kWh_{th}$ $146kWh_{e}$	$1395kWh_{th}$ $209kWh_{e}$
CAPEX	€443,000	€443,000
Year 1 Expenditure	-€109,000	-€133,000
Year 1 Revenue	€15,000	€22,000
Total Year 1 Cash flow	-€94,000	-€111,000
NPV	**-€1,782,000**	**-€2,033,000**
OHC	**€72/MWh**	**€60/MWh**
THC	**€91/MWh**	**€73/MWh**

Table 7: Scenario 2 Assessment

Scenario 2 has the highest OHC and THC values of all the scenarios analysed, indicating that it represents the worst economic value of all the scenarios. Therefore even if this scenario was cost free (CAPEX = €0) it would still not be beneficial to install this unit over the baseline scenario.

The main reason for this is that the thermal output of the Stirling DK unit is rated at $420kW_{th}$, yet the average Ecovillage thermal load is only $150kW_{th}$ and $210kW_{th}$ for annual thermal loads of 1300MWh and 1860MWh respectively. No thermal load profile data was available so it was assumed that the Stirling DK unit would supply 75% of the Ecovillage thermal load, resulting in capacity factors of only 27% and 38% for annual thermal loads of 1300MWh and 1860MWh respectively. Feedback during market research indicated that biomass CHP units typically need to be running at a capacity factor >90% in order to represent greater economic value than biomass boilers. This could be addressed by using a smaller generation unit, yet this would then break the requirement to be able to supply the peak load of $910kW_{th}$.

If it transpires through operational data that the peak load is <$910kW_{th}$ and it is possible to use a smaller Stirling DK unit, then it is likely that that unit would run at a higher capacity factor and so represent better economic value. Alternatively, and due to the modular nature of the combustion chambers of the Stirling DK units, it may be possible to normally run the units to produce $210kW_{th}$, still produce $70kW_{e}$ and yet retain a thermal generation capacity of $420kW_{th}$. This would result in an increased capacity factor, and an improved economic case. This option was not analysed due to the large number of unknowns regarding the Ecovillage thermal load profile.

Secondary reasons for the poor economic performance of scenario 2 are a much greater CAPEX than the baseline scenario and scenario 1, and a greater annual maintenance costs than any other scenario – roughly double those of the other biomass CHP units. It may be that the expected maintenance costs supplied by other manufacturers were very optimistic. However, even when the annual fixed costs (which includes the maintenance cost) of the other two units were set the same as the Stirling DK unit, it still had the highest OHC and THC values. These results indicate scenario 2 is the least economically beneficial option.

7.4 Scenario 3 – Talbott's Unit

Table 8 details the results from the economic assessment of scenario 3.

	Annual Thermal Load 1300MWh	Annual Thermal Load 1860MWh
Annual CHP Generation	780kWh$_{th}$ 351kWh$_{e}$	1116kWh$_{th}$ 502kWh$_{e}$
CAPEX	€518,000	€518,000
Year 1 Expenditure	-€97,500	-€125,500
Year 1 Revenue	€34,500	€49,000
Total Year 1 Cash flow	-€63,000	-€76,500
NPV	**-€1,406,000**	**-€1,594,000**
OHC	**€49/MWh**	**€41/MWh**
THC	**€72/MWh**	**€57/MWh**

Table 8: Scenario 3 Assessment

Scenario 3 has the second highest THC all the scenarios, meaning that the baseline scenario and scenario 1 both represent better economic value.

Scenario 3 does however have the lowest OHC and the highest annual revenue of all scenarios, indicating that its poor THC ranking is due to its high CAPEX. However further analysis showed that to equal the THC of scenario 1, the scenario 3 CAPEX would have to be reduced by approximately 50%, deemed to be unrealistic in any future scenario. This would indicate that, given the much greater electrical generation capability over scenario 1, the Talbott's unit may only realistically be able to represent better economic value than the Electratherm unit in the case of increased revenue from electricity offset and export. This is studied further in Section 8.

7.5 Comparison of Scenarios

Table 9 summarises the economic assessment work.

	Annual Load (MWh)	CAPEX (€k)	NPV (€k)	OHC (€k/MWh)	THC(€k/MWh)
Baseline	1300	0	-1,011	55	52
	1860	0	-1,305	49	47
Scenario 1	1300	145	-1,142	53	59
	1860	145	-1,412	47	51
Scenario 2	1300	443	-1,782	72	91
	1860	443	-2,033	60	73
Scenario 3	1300	518	-1,406	49	72
	1860	518	-1,594	41	57

Table 9: Summary of Economic Assessments

Table 9 shows that the baseline scenario has the lowest THC of all scenarios analysed for annual thermal loads of 1300MWh and 1860MWh, indicating that under current conditions it is not economical to pursue any of the three biomass CHP scenarios analysed.

This finding assumes that for the baseline scenario the CAPEX = €0 as the baseline scenario has in effect already been paid for and the infrastructure is already installed. To take account of this, further analysis was undertaken for a baseline scenario where there was no existing infrastructure, and so the baseline scenario CAPEX ≠ €0 as biomass boilers would have to be purchased to supply the Ecovillage thermal load. Even in this case, it may still be more economical to install biomass boilers rather than biomass CHP, because the biomass CHP units analysed require additional thermal generation to meet the Ecovillage thermal load. Therefore, for this new baseline condition, the CAPEXs of scenarios 1, 2 and 3 would also increase as additional thermal generation capability would need to be purchased.

Table 9 shows that scenario 1 and 3 have lower OHC values than the baseline scenario. The OHC value does not take into account CAPEX, indicating that under current conditions it would not be economical to pursue scenario 2, even if it were cost free. The poor economic performance of scenario 2 can be explained primarily by its lower capacity factor.

Table 9 shows that the THC decreased for all scenarios under the greater annual thermal load of 1860MWh. Furthermore, the biomass CHP scenarios 1, 2 and 3 show a greater difference in THC values for supplying 1860MWh versus 1300MWh than the baseline scenario, indicating that in order for any biomass CHP unit to be economical viable, it would have to operate at the highest capacity factor possible by being the lead thermal generation. This is to be expected as, even though annual fuel costs increase to supply the increased thermal load, the CAPEX and fixed OPEX decrease as a proportion of thermal energy generated.

In summary, under current economic and market conditions and for a project of this size, it is unlikely that there would be any situation where it would be economical to install biomass CHP instead of or in addition to biomass boilers.

8 Future Cost Analysis

The analysis work undertaken to assess the economic benefit of installing biomass CHP instead of or in addition to biomass boilers (Section 7) has shown that under current economic and market conditions there is no case where it would be economically beneficial to do so. The Tipperary Institute has a requirement to understand the impact on the economic feasibility of biomass CHP that the introduction of the proposed REFIT II and varying electricity and biomass fuel costs may have.

Section 8.1 assesses the impact on the scenarios analysed in Section 7 of the introduction of REFIT II, assuming no other parameters change. Sections 8.2 and 8.3 assess the impact of varying electricity and biomass fuel costs on the overall feasibility of biomass CHP, as ranked by THC, under REFIT and REFIT II respectively and for an annual thermal load of 1860MWh.

8.1 REFIT II

In 2006 Ireland introduced the REFIT to provide financial support to renewable energy projects, which currently offers biomass generators 8.4c/kWh for electricity exported. The REFIT II is the proposed extension of that scheme which would offer an increased tariff of 12c/kWh to biomass powered high efficiency CHP projects, for which it is assumed that the Ecovillage project would be eligible. The REFIT II is currently under review by the EU, but it is predicted that it should be in place within two years – the likely earliest installation date of any biomass CHP, as indicated by Seamus Hoyne (SERVE project manager).

The economic analysis undertaken in Section 7 was rerun using the REFIT II tariff of 12c/kWh. Table 10 summarises the results.

	Annual Load (MWh)	CAPEX (€k)	NPV (€k)	OHC (€k/MWh)	THC(€k/MWh)
Baseline	1300	0	-1,011	55	52
	1860	0	-1,305	49	47
Scenario 1	1300	145	-1,142	53	59
	1860	145	-1,412	47	51
Scenario 2	1300	443	-1,748	70	90
	1860	443	-1,984	58	71
Scenario 3	1300	518	-1,293	43	66
	1860	518	-1,433	35	51

Table 10: Summary of Economic Assessments under REFIT II

Table 10 shows that the introduction of the REFIT II tariff of 12c/kWh would increase the economic benefits of scenarios 2 and 3. It does not improve the economic case for the baseline scenario or scenario 1 as the tariff would only be paid for energy exported, and no electricity is generated in the baseline scenario, and under scenario 1 all electricity generated is used to offset the Energy Centre loads and so there is no export. The introduction of the tariff would not change the overall ranking of the scenarios with regard to OHC or THC.

In summary, whilst the REFIT II would increase the economic value of biomass CHP, it is still the case that should other economic parameters remain unchanged, it is unlikely that it would be economical to install biomass CHP instead of or in addition to biomass boilers.

8.2 Electricity vs. Biomass Cost (REFIT)

The model has been run multiple times to assess the impact on the overall economic feasibility of biomass CHP of varying potential future electricity and biomass fuel costs. This section presents the results ranked by THC, under the current REFIT tariff of 8.4c/kWh and for an annual thermal load of 1860MWh.

The results have been plotted in Figure 5 and show which scenario has the lowest THC value for each value of future electricity cost and future woodchip fuel cost. The black bordered square indicates the current biomass and electricity cost (€110/tonne and 12c/kWh respectively).

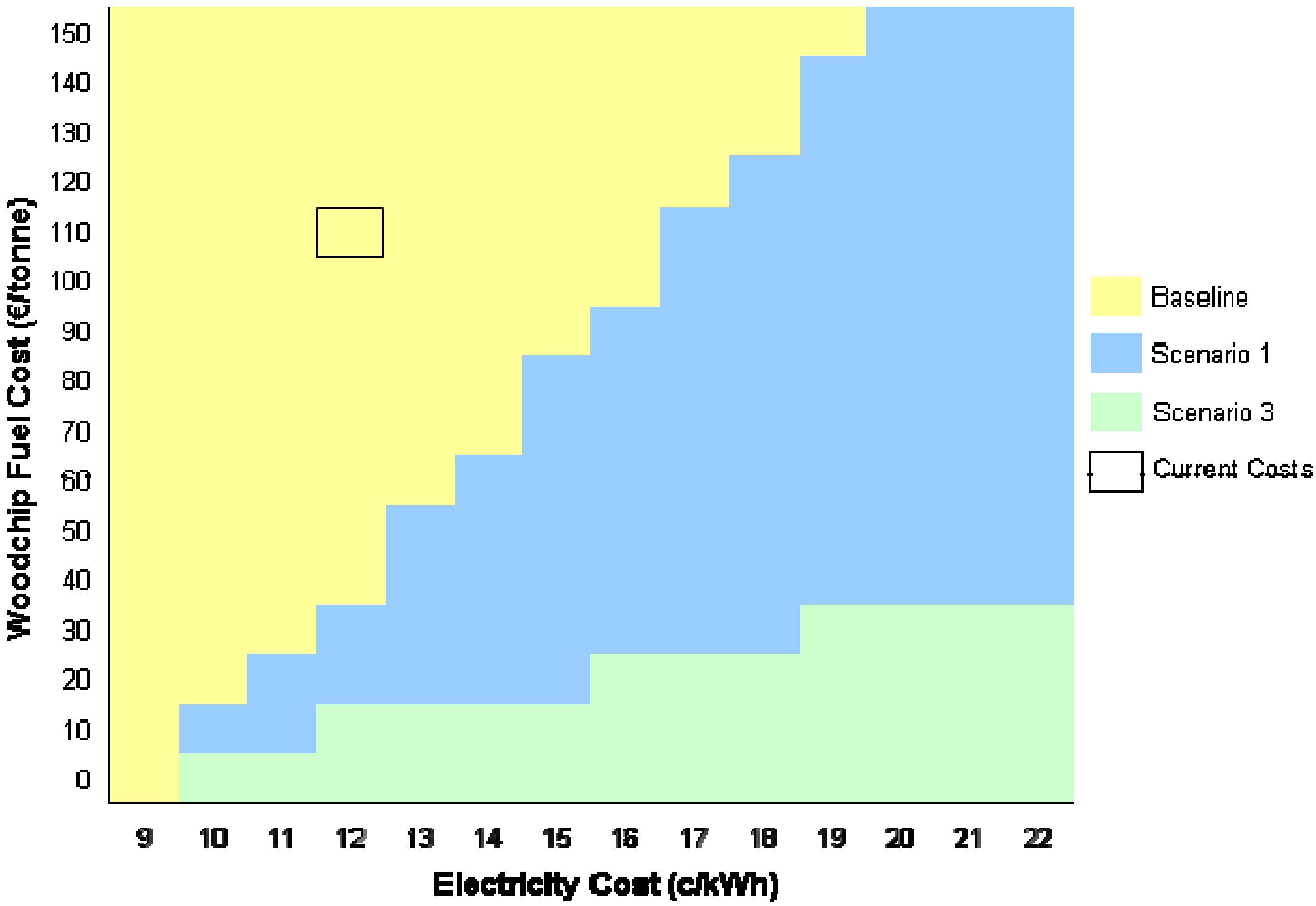

Figure 5: THC Ranking under REFIT

Figure 5 indicates that a notable decrease in biomass fuel costs or increase in electricity costs would be required for biomass CHP to become economically beneficial over the baseline scenario. If the biomass fuel cost were to remain constant, then the electricity cost would have to increase to approximately 17c/kWh for scenario 1 to have a lower THC than the baseline scenario. If the electricity cost were to remain constant, then the biomass fuel cost would have to decrease to €30/tonne for scenario 1 to have a lower THC than the baseline scenario. However if the cost of electricity were to only increase to 13c/kWh, then the biomass fuel cost would only have to decrease to €50/tonne instead.

Figure 5 illustrates that in the event that a very low cost source of biomass fuel is found, then it is likely that scenario 3 rather than scenario 1 will represent the best economic value. In the event that a free source of biomass fuel was found, such as waste wood from a timber merchant, biomass CHP would become economically beneficial over the baseline scenario providing that the cost of electricity was notably greater than 9c/kWh. If biomass fuel cost were to increase with no corresponding increase in electricity costs, then biomass CHP will remain uneconomical compared to biomass boilers.

Within the range of biomass and electricity costs analysed and shown in Figure 5, at no point did scenario 2 have the lowest THC values – this corresponds with the findings detailed in Section 7.

8.3 Electricity vs. Biomass Cost (REFIT II)

The model was run again multiple times, but this time using the proposed REFIT II tariff of 12c/kWh instead of the current REFIT tariff of 8.4c/kWh. As in Section 8.2, the results were ranked by THC for an annual thermal load of 1860MWh.

The results have been plotted in Figure 6 and show which scenario has the lowest THC value for each value of future electricity cost and future woodchip fuel cost. The black bordered square indicates the current biomass and electricity cost (€110/tonne and 12c/kWh respectively).

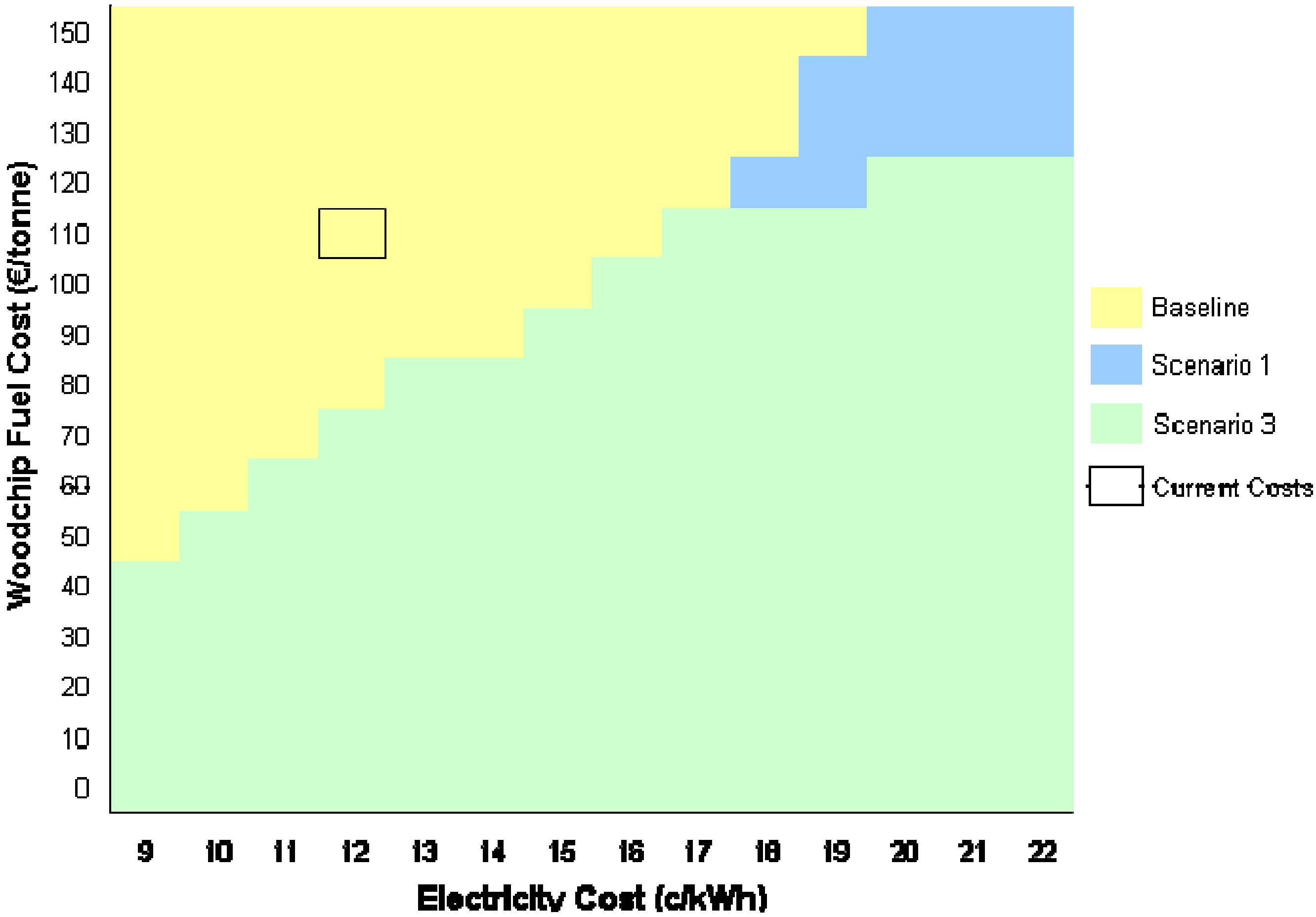

Figure 6: THC Ranking under REFIT II

Figure 6 indicates that the introduction of the REFIT II would promote scenario 3 over scenario 1 as being the most economically beneficial biomass CHP scenario in most cases for the range of biomass fuel and electricity costs analysed.

Figure 6 indicates that a decrease in biomass fuel costs and increase in electricity costs would still be required for biomass CHP to become economical viable under REFIT II, but those changes in cost aren't as substantial as those required under REFIT. If the biomass fuel cost were to remain constant, then the electricity cost would still have to increase to approximately 17c/kWh for scenario 3 to have a lower THC than the baseline scenario. If the electricity cost were to remain constant, then the biomass fuel cost would only have to decrease to €70/tonne, instead of

€30/tonne under REFIT, for scenario 3 to have a lower THC than the baseline scenario. In the case that a free source of biomass fuel was found, scenario 3 would remain economically beneficial over the baseline scenario providing that the cost of electricity was greater than 4c/kWh. Therefore it can be concluded that the introduction of the REFIT II would improve the economic feasibility of biomass CHP in the case of lower biomass fuel costs.

Within the range of biomass and electricity costs analysed and shown in Figure 6, at no point did scenario 2 have the lowest THC values – this corresponds with the findings detailed in Section 7.

8.4 Summary

The future cost analysis found that:

- The introduction of the REFIT II will promote the economic viability of biomass CHP, but only for biomass CHP schemes that have enough electrical generation capacity to offset the site load and so export to the grid.
- Rising electricity costs and falling biomass fuel costs will promote biomass CHP over biomass boilers.
- If electricity and wood fuel costs remain unchanged, or if electricity costs fall and biomass fuel costs rise, then biomass boilers will remain more economically viable than biomass CHP, even with the introduction of REFIT II.
- Falling biomass fuel costs under REFIT II will provide the most favourable economic conditions for biomass CHP

In summary, even with the introduction of REFIT II, notable changes in both biomass fuel and electricity cost would be required in order that biomass CHP becomes economically viable. It is unlikely that these required changes will take place within two years – the likely earliest installation date of any biomass CHP as indicated by Seamus Hoyne – and so it does not seem good economic value to pursue a biomass CHP option at this time.

The exception to this may be in the case that a very cheap or free fuel source can be sourced, such as waste wood from a timber merchant, in which case biomass CHP may be economically beneficial, even under the existing REFIT and with current electricity costs. However under the existing REFIT, if the current electricity cost were to fall below 10c/kWh, it is unlikely that that biomass CHP would be economically beneficial, even in the event of a free fuel source.

9 Error Analysis

This section provides an indication of the accuracy of the results presented in Section 8, and in particular details how the results are affected by changes to the assumptions made and the input data to the model.

Figure 5 and Figure 6 in Section 8 show which scenario had the lowest THC, and so which represented the best economic value. Along the economic feasibility borders – the borders which mark when the scenario with the lowest THC value changed (where the colours change on the graphs) – the percentage difference between the two relevant scenarios was usually less than 5%. This is well within expected error bounds for analysis work of this nature. Therefore even small changes in parameters such as unit efficiency, CAPEX, OPEX, can change the THC profile.

This is demonstrated in Figure 7 below. Figure 7 shows which scenario has the lowest THC value for varying biomass fuel and electricity costs under the existing REFIT tariff (i.e. the analysis presented in Figure 5 in Section 8.2). The only values that differ between Figure 5 and Figure 7 are:

- Existing boiler efficiency is 95% in Figure 7, as opposed to 90% in Figure 5.
- Electratherm unit efficiency is 40% in Figure 7, as opposed to 50% in Figure 5.
- Talbott's unit efficiency is 75% in Figure 7, as opposed to 80% in Figure 5.

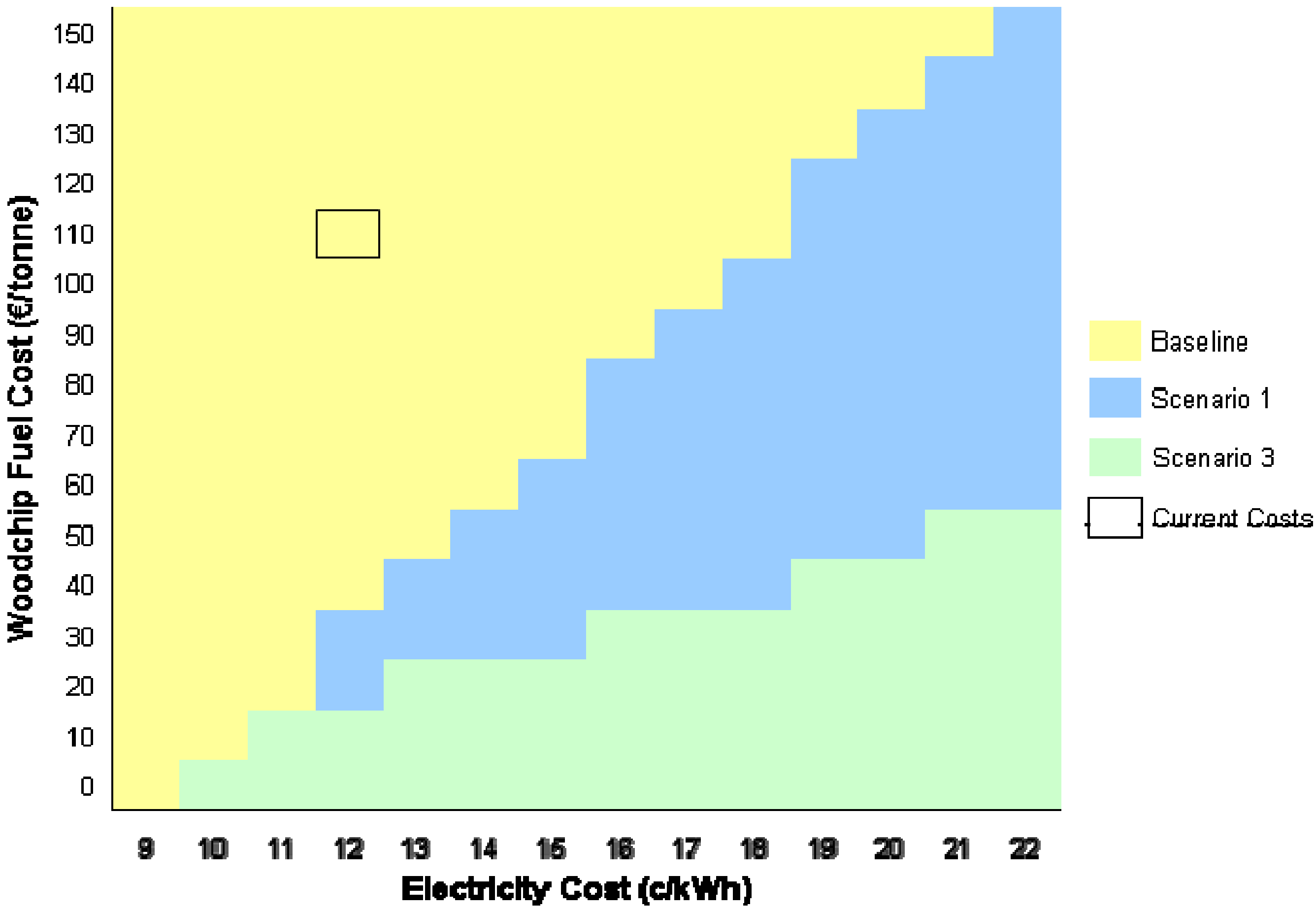

Figure 7: Error Analysis Example for Future Cost Analysis

When comparing Figure 5 and Figure 7, it can be observed that whilst the minor changes have not changed the general trends, the areas where the baseline scenario and scenario 3 have the lowest THC values has increased, and the economic feasibility border between the baseline scenario and scenario 1 has moved away from the current position, indicating that greater increases in electricity cost and greater decreases in biomass costs are required for biomass CHP to become economically viable.

This is of particular importance as it is Senergy Econnect's opinion that in the future it is likely that the cost of electricity will increase. This would move the current costs towards the economic feasibility border between the baseline scenario and scenario 1 (where the colour changes from yellow to blue) – the area where the difference in THC values and rankings is the smallest and so most liable to change.

Therefore it should be stressed that the findings in this report should be used to highlight general trends and compare the relative merits of biomass boilers as opposed to biomass CHP, and not to provide exact values for NPV or THC for individual scenarios.

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10 Conclusion

The Tipperary Institute commissioned Senergy Econnect to undertake a cost benefit analysis of installing biomass CHP instead of or in addition to the existing biomass boiler heating system at the Cloughjordan Ecovillage in County Tipperary, Ireland.

Senergy Econnect undertook extensive market research to identify potentially suitable biomass CHP units. The market research highlighted that the small scale biomass CHP market, into which the Ecovillage project would fit, currently has very few established and respected manufacturers or reliable tried and tested products. From the range of manufacturers that do supply this market, very few have a large portfolio of successful case studies.

Based on market research and the requirements of the Ecovillage project, three biomass CHP units were identified as being potentially suitable. These are listed in Table 11.

Manufacturer	Technology	Thermal/Electrical Power (kW)	Efficiency	Cost
Electratherm	ORC	0 / 50	50%	£120,000
Stirling DK	Stirling Engine	420 / 70	83.5%	€480,000
Talbott's	Microturbine	200 / 90	80%	£459,000

Table 11: Biomass CHP Units for Assessment

Based on the generation capacities of these units, a number of assessment scenarios were formulated for economic assessment:

- **Baseline Scenario**. The current boiler heating system assuming no system changes.
- **Scenario 1**. The retrofitting of one $50kW_e$ Electratherm ORC unit to the existing Ecovillage boiler heating system, i.e. both existing boilers retained.
- **Scenario 2**. The replacement of one of the existing biomass boilers with one $420kW_{th}$ $70kW_e$ Stirling DK updraft gasifier Stirling engine unit.
- **Scenario 3**. The addition of one $200kW_{th}$ $100kW_e$ Talbott's microturbine unit to the existing Ecovillage heating system, i.e. both existing boilers retained.

These four scenarios were economically assessed to find the capital cost (CAPEX), net present value (NPV), operational heat cost (OHC) and total heat cost (THC). These assessments were done for current market conditions and for a minimum and maximum annual thermal load of 1300MWh and 1860MWh respectively. Table 12 summarises the results from this analysis.

	Annual Load (MWh)	CAPEX (€k)	NPV (€k)	OHC (€k/MWh)	THC(€k/MWh)
Baseline	1300	0	-1,011	55	52
	1860	0	-1,305	49	47
Scenario 1	1300	145	-1,142	53	59
	1860	145	-1,412	47	51
Scenario 2	1300	443	-1,782	72	91
	1860	443	-2,033	60	73
Scenario 3	1300	518	-1,406	49	72
	1860	518	-1,594	41	57

Table 12: Summary of Economic Assessments

Table 12 shows that the baseline scenario has the lowest THC of all scenarios analysed for annual thermal loads of 1300MWh and 1860MWh. The biomass CHP scenarios (1, 2 and 3) show a greater difference in THC values for supplying 1860MWh versus 1300MWh than the baseline scenario, indicating that in order to increase the economic feasibility of biomass CHP against the baseline scenario, biomass CHP should be run at the highest possible capacity factor. The OHV values in Table 12 indicate that under current economic conditions it would not be economical to pursue scenario 2, even if it were capital cost free (CAPEX = €0). The poor economic performance of scenario 2 can be explained primarily by its low capacity factor. Therefore, under current economic and market conditions it does not seem economical to pursue any of the three biomass CHP scenarios analysed.

The Tipperary Institute had a further requirement to understand the impact on the economic feasibility of biomass CHP due to the introduction of the proposed REFIT II tariff of 12c/kWh, and variability of electricity and biomass fuel costs. This further analysis found that:

- The introduction of the REFIT II framework will improve the economic viability of biomass CHP, but only for biomass CHP schemes that have enough electrical generation capacity to offset the site load and so export to the grid. Should other economic parameters remain unchanged, then it is still the case that it is unlikely that it would be economical to install biomass CHP instead of or in addition to biomass boilers.
- Increasing electricity costs and decreasing biomass fuel costs will improve the economic viability of biomass CHP over biomass boilers. For biomass CHP to be economically viable under the current REFIT framework, the cost of electricity would have to be greater than 17c/kWh, or the cost of biomass fuel would have to be lower than €30/tonne. For biomass CHP to be economically viable under the proposed REFIT II framework, the cost of electricity would have to be greater than 17c/kWh, or the cost of biomass fuel would have to be lower than €70/tonne.
- In the event that a very cheap or free biomass fuel source can be sourced, such as waste wood from a timber merchant, biomass CHP may be economically beneficial, even under the existing REFIT framework and with current electricity costs. If the biomass fuel source is free, it is economical to pursue biomass CHP providing that the cost of electricity is greater than 10c/kWh under the current REFIT framework, and greater than 4c/kWh under the proposed REFIT II framework.

Error analysis undertaken on the results showed that small changes in the model parameters resulted in changes in THC ranking along the economic feasibility borders – the borders which mark out which scenario has the lowest THC value for given parameter values – but the general trend that biomass CHP feasibility increases with increasing electricity costs and decreasing biomass fuel costs did not change. Therefore it should be stressed that the findings in this report should be used to highlight general trends and compare the relative merits of biomass boilers as opposed to biomass CHP, and not to provide exact values for NPV or THC for individual scenarios.

Other factors that may improve the future viability of biomass CHP include the introduction in Ireland of a scheme similar to the RHI, that is currently under consultation for the UK, which may offer a revenue scheme for the thermal energy generated by biomass CHP projects, and the development and growth of the small scale biomass CHP market with an increase in the number, efficiency and value of its products.

To conclude, under current economic and market conditions it does not seem economical to pursue any of the three biomass CHP scenarios analysed. Even with the introduction of REFIT II, notable changes in the cost of both biomass fuel and electricity would be required in order that biomass CHP becomes economically viable. It is unlikely that these required changes will take place within two years – the likely earliest installation date of any biomass CHP – and so it does not seem good economic value to pursue a biomass CHP option at this time.

The models created by Senergy Econnect to provide the results in this report could be re-run at a later date, subject to available budget under the SERVE project, should the economic assumptions made in this report change significantly.

11 References

1. REMS 'Cost Report', supplied by Seamus Hoyne by email dated 02/02/2010.
2. Concerto Initiative 'RES Ecovillage Demonstration Progress Report', Deliverable 4.1 Work Package 4, 05/12/2008.
3. Herz 'Woodchip/Pelletboiler HERZ BioMatic BioControl 220-500kW English', [Online]. Available at http://www.herz-feuerung.com/.
4. Emails from Trevor Buttimer (REMS) to Julian Wayne (Senergy Econnect) dated 16/03/2010 and 18/03/2010.
5. SERVE 'D7.1: Specification for Green Electricity Purchasing'. Authored by Senergy Econnect.
6. Minutes of Christine Barbier's site visit on 01/12/2009 and 02/12/2009, authored by Christine Barbier (Senergy Econnect).
7. SERVE 'D7.2c: Report on Medium Wind land Load Control in Utility Area of Eco Village'. Authored by Senergy Econnect.
8. Email and telephone correspondence with Don Lord (UK Biomass Ltd) between 25th February and 1st March 2010.
9. Patrick Lamb, Tipperary Institute 'Business Plan; Cloughjordan District Heating System', September 2009.

12 Appendix A – Herz BioMatic Boiler

Figure 8 is a cut-through diagram which details the internal layout of the Herz BioMatic 500 Biocontrol boilers [3].

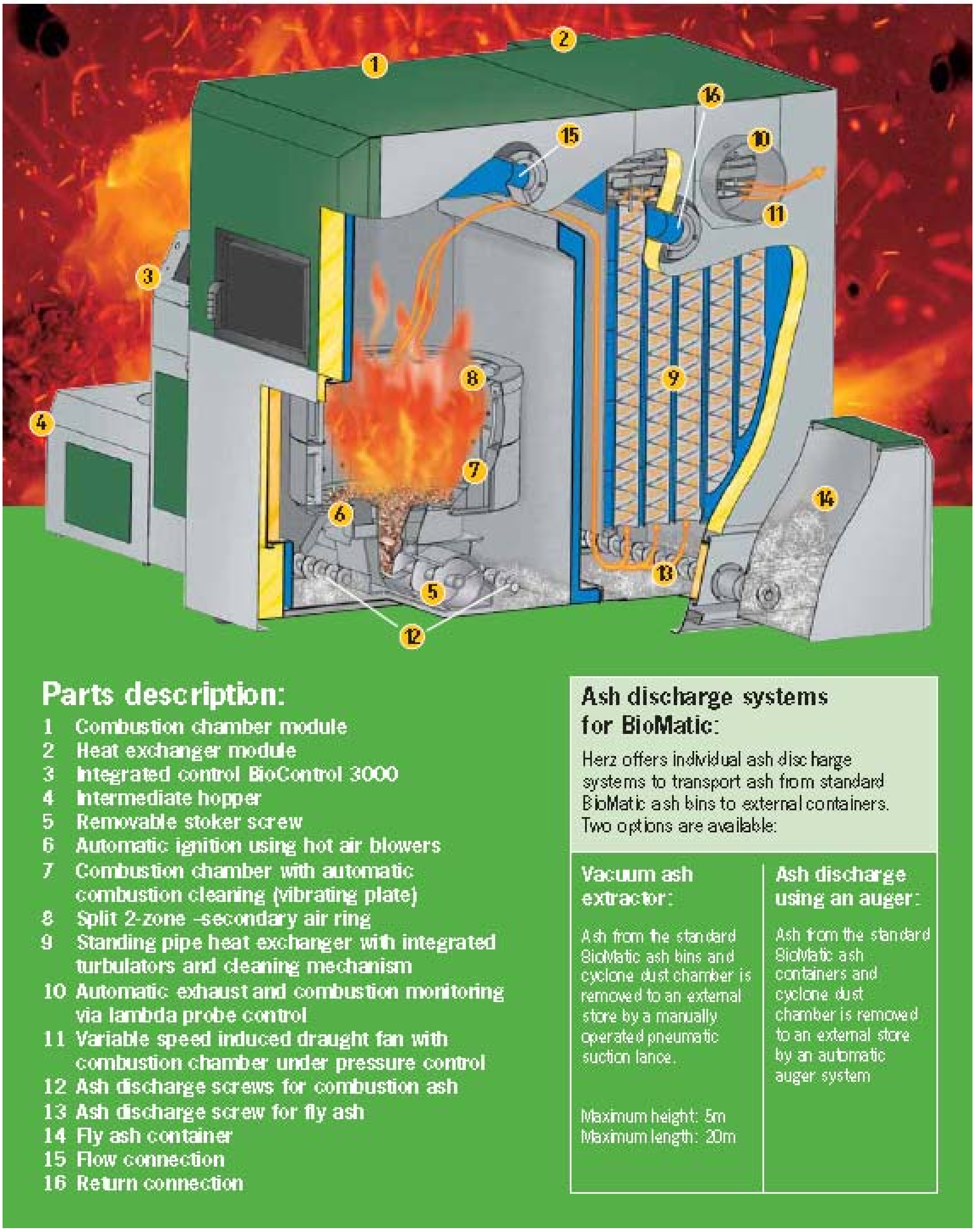

Figure 8: Herz BioMatic Boiler Diagram

13 Appendix B – Predicted Thermal Loads

The predicted Ecovillage thermal loads are based on information received from Trevor Buttimer [4], and all values are from that reference unless stated otherwise.

13.1 Annual Load Calculation

The annual thermal load has been estimated at 1,300-1,500MWh/year, of which it is estimated that 200-250MWh will be supplied by solar thermal. The remainder is currently supplied by the biomass boilers, and so would have to be met by any replacement biomass CHP.

Taking a district heating system efficiency value of 70%, the theoretical range for annual thermal load can therefore be calculated as:

$$Min\,Load = \frac{1300-250}{0.7} = 1500 MWh / year$$

$$Max\,Load = \frac{1500-200}{0.7} = 1860 MWh / year$$

13.2 Peak Load Calculation

Peak load (PL) was calculated as:

Peak Load = Peak load/house × number of houses × diversity factor

where the diversity factor is the estimated proportion of houses that will be drawing peak load at the same time and is stated as being 0.7 [4]. Therefore the peak load (PL) can be calculated as:

$$PL = 10kW \times 130 \times 0.7$$

$$\Rightarrow PL = 910kW$$

14 Appendix C – Baseline OPEX

This Appendix details the calculations for the predicated annual OPEX for the existing biomass boilers. Two OPEX values are calculated for predicted annual loads of 1300kWh and 1860kWh (see Appendix B). Data on fuel cost is from Patrick Lambe's business plan for SPIL [9].

14.1 Biomass Fuel Cost

Table 13 calculates the annual biomass fuel cost for the existing biomass boilers:

	Annual Load 1300MWh	**Annual Load 1860MWh**
Specific Heat Value	3.4kWh/kg	3.4kWh/kg
→Annual Biomass Fuel Requirement* (rounded values)	**425,000kg**	**610,000kg**
Biomass Fuel Cost[4] (inc delivery)	€110/tonne	€110/tonne
→Annual Cost of Biomass Fuel	**€46,500**	**€67,000**

Table 13: Annual Biomass Fuel Cost for Existing Boilers

*Assuming boiler η=90%

14.2 Predicted Annual OPEX

Table 14 details the predicted annual OPEX for the existing boilers. It is assumed that aside from electricity and biomass fuel cost, the other costs will not vary for changes in annual load between 1,300-1860MWh/year.

	Cost (€) **Annual Load 1300MWh**	**Cost (€)** **Annual Load 1860MWh**
Biomass Fuel (variable)	47,500	68,750
Optimisation (fixed)	2,000	2,000
Supervision and Billing (fixed)	3,000	3,000
Maintenance Contract (fixed)	8,000	8,000
Insurance (fixed)	1,000	1,000
Operative Salary (fixed)	8,500	8,500
Administration (fixed)	2,000	2,000
TOTAL	**72,000**	**93,250**

Table 14: Annual OPEX for Existing Boilers

[4] Moisture content = 35%

15 Appendix D – Biomass CHP OPEXs

This Appendix sets out the predicted maintenance and running costs for the biomass CHP units used in the economic assessment scenarios (Section 7), and the rational behind them. Fuel costs are not included in this Appendix.

The three manufacturers provided indicative maintenance costs which have been used. The other OPEX costs have been predicted by making sensible adjustments to those set out in Patrick Lambe's business plan [9] for the current system. Table 15 details these predicted costs.

	Scenario 1 OPEX Electratherm	Scenario 2 OPEX Stirling DK	Scenario 3 OPEX Talbott's
Optimisation	€2,500	€3,000	€3,000
Supervision and Billing	€3,000	€3,000	€3,000
Maintenance Contract	€9,700	€25,000	€12,500
Insurance	€1,500	€2,000	€2,000
Operative Salary	€9,400	€17,000	€10,200
Administration	€2,500	€4,000	€2,500
TOTAL	**€28,600**	**€54,000**	**€33,200**

Table 15: Biomass CHP OPEXs

The rational behind the OPEX values is as follows:

- **Optimisation**. The Electratherm unit will automatically produce electricity when the existing boilers operate, so it is assumed that minimal additional system optimisation is required. The Stirling DK and Talbott's units will both require new control and synchronisation with the solar array and DH system, and so are increased on the current optimisation costs.
- **Supervision and Billing**. It is understood that metering will be undertaken by smart meters, so no additional supervision or billing costs are foreseen.
- **Maintenance contract**. This includes average annual cost of replacement parts. The Electratherm has an annual maintenance cost of £1,500[5], in addition to the €8,000 of the existing system. The Stirling DK unit has an annual maintenance cost of approximately €20,000, in addition to the annual maintenance cost of the one remaining boiler assumed to be €5000. The Talbott's unit has an annual maintenance cost of approximately £4,400, in addition to the €8,000 of the existing system.
- **Insurance**. It is assumed that the lack of numerous successful case studies for each unit will be seen as an increased risk by the insurance company. The Electratherm is a sealed system with no thermal generation, so it is assumed it will be perceived as being less risky. It is assumed that the Stirling DK and Talbott's units will be perceived as being more risky, and so a doubling of the existing insurance costs is not an unreasonable assumption.
- **Operative Salary**. It is assumed that the operation of the Electratherm unit will require a 10% increase in annual operative resource, the operation of the Stirling DK unit will require a doubling of operative resource, and the Talbott's unit will require a 20% increase in operative resource.
- **Administration**. It is assumed that the operation of any of the units will result in a 25% increase in administration resource.

If more detailed OPEX values become available due to experience from existing projects, then this Appendix and the costing model can be updated accordingly.

[5] Graham Lebeter email dated 1 April 2010.