An Analysis of Ireland's Renewable Thermal Energy Policy Target

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Executive summary

Escalating oil and gas prices due to increased demand from emerging economies and a lack of political instability in major oil and gas producing regions have led to increased focus for Ireland's energy demand to be supplied from indigenous renewable sources. In addition to these economic issues various environmental issues such as global warming and a focus on developing sustainable energy have become more important at a national and international level. In 2007, the European Union agreed new climate and energy targets, 20-20-20 by 2020 – 20% reduction in greenhouse gas emissions by 2020; 20% energy efficiency by 2020 and 20% of the EU's energy consumption to be from renewable sources by 2020.

In Wake of this the EU directive 2009/28/EC (promotion of the use of energy from renewable sources) was formed. From this directive the Irish Government published a White paper on Energy Policy displaying Ireland's ambition for renewable energy with individual targets set for each of the three distinct energy markets, namely the electricity, transport and thermal energy markets. The White Paper targets are set for the year 2020, with interim targets to be met by 2010.

According to Richard Browne from the Department of Communications, Energy and Natural Resources we may have failed to meet the interim target of 5% for thermal renewable energy This study investigates the renewable thermal target of 12% for 2020 looking at how we will meet the target giving that projections for thermal energy show that the demand is decreasing due to the slowdown in economic activity. The thermal energy market in Ireland is defined as the energy used for space, process and water heating, cooking etc. *[Department of communications, energy and natural resources, 2007]*. Investigation in this study also looks at how we currently produce our thermal energy, support schemes to promote renewable energy in heating and cooling and forecasts used when producing thermal energy and the assumptions these forecasts are based on.

This study contributes significantly to the knowledge in the area of renewable thermal energy production and forecasting and upon completion of this study the author will determine if Ireland can meet the 12% target by 2020.

Acknowledgements

First and foremost I would like to express my appreciation and sincere thanks to my supervisor, Dr. Denis O'Mahoney, who has supported me from start to finish in this thesis. Through his experience, patience and knowledge he has provided me with the best experience to learn and develop new skills while researching this thesis, whilst keeping me motivated.

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Finally, and most importantly, I would like to express my since gratitude to all members of my family who have provided me with continued support throughout my postgraduate year, without them this thesis would not have been possible. Your help was much appreciated.

Abstract

"Ireland has ambitious short- and medium-term targets for renewable energy deployment and faces a number of significant challenges to meet them".

The Irish government released "The White Paper on Energy Policy" in 2007 which made public its ambitious targets for energy consumption areas to be supplied from renewable sources by 2020 *[(Department of communications, energy and natural resources, 2007)]*. As the need to decouple industrial development and carbon emissions increases, more emphasis is being placed on renewable technologies. In recent years, this focus has seen a considerable rise in the penetration of renewable energy to the electricity and transport sectors, primarily through wind turbines, the introduction of electric road vehicles and mandatory biofuel obligations. Ireland has a preoccupation with renewable electricity, with targets for 40% renewable contribution to be met by 2020. This is accommodated by a favourable regulatory environment for developers of renewable electricity projects. However, Ireland must also make significant progress in the thermal energy sector in order to accomplish the overall renewable target of 16%, since achieving 40% renewable electricity will only constitute 7% renewables overall. The Government plan to realise the EU target includes a 12% renewable contribution to thermal energy. Based on the energy projections released by the SEI, this would require a tripling of renewable thermal usage to the range of 580 - 680 ktoe which is a 10% increase yearly to 2020.

While no explicit European Union (EU) target for Ireland exists in the thermal energy area, a national target of 12% Renewable Energy Source -Heat as set down in the 2007 Energy White Paper. The target being investigated in this research is the 12% thermal energy target. This target will prove to be a huge challenge as Ireland has already marginally failed to meet its 5% target by 2010. Renewable heat (RES-H) accounted for 3.6% of all thermal energy in 2008. RES-H grew from 2.6% in 1990 to 3.8% in 2004 but has not grown significantly since, indicating a gap to the short-term Government target of 5% RES-H to be met by 2010.

This thesis explores the projections for thermal energy production and consumption levels to the year 2020 and examines the many technologies which can aid the realisation of this target. Renewable thermal energy can be generated by direct combustion of solid biomass or through the anaerobic digestion of wet biomass to biomethane with subsequent injection into the natural gas grid. Alternative methods of producing renewable heat such as geothermal heat pumps and solar thermal are also considered in this study. Forest wood, waste wood and the utilisation of excess arable land for the production of miscanthus could generate 554.5 ktoe of renewable heat. From this feedstock, 53.4 ktoe could easily be combusted in viable district heating schemes. The energy potential from biomethane is much larger at 1,618 ktoe and could be captured through the digestion of organic wastes diverted from landfill and residues or energy crops such as grass. Effective targeting of solar thermal and heat pumps have been shown to be capable of substituting 42.64 ktoe of thermal energy.

Nomenclature

AD – Anaerobic digestion

AER – Alternative energy requirement

BMS – Building management system

CAD - Centralised anaerobic digester

CCGT – Combined Cycle Gas Turbine

CER – Commission for Energy Regulation

CHCP – Combined heating and cooling plant

CHP – Combined heat and power

COP – Coefficient of performance

CSO – Central Statistics Office

DH –District heating

DHW – Domestic hot water

DoAF - Department of Agriculture and Food

DoEHLG - Department of Environment, Heritage and Local Government

DS – Dry solids

EPA - Environmental Protection Agency

ERI – Energy Research Institute, UCC

ET – Evacuated tube solar collector

EU – European Union

ghg – Green house gas

GJ – Gigajoule (1 x 109 joules)

GSHP – Ground source heat pump

ha –Hectares

IPCC - Intergovernmental Panel on Climate Change

kg – Kilogram

m^2 – Meter squared

m^3 - Meter cubed

Mc - moisture content

MJ – Megajoule (1 x 106 joules)

MW – Megawatts (1 x 106 watts)

MWh – Megawatt hour (1 x 106 watt hours)

NPV – Net present value

MWe – Megawatt electricity

MWt – Megawatt thermal

OFMSW – Organic fraction of municipal solid waste

Pa – Pascal

PE – Population equivalent

PP – Payback Period

REFIT – Renewable energy feed in tarrif

ReHEAT – Renewable heat deployment programme

RES-H – Renewable energy Supply – heat

RES-T – Renewable energy supply - transport

SEAI – Sustainable Energy Authority Ireland

t - Tonne

toe – Tonnes oil equivalent

UNFCCC – United Nations Framework Convention on Climate Change

η – Efficiency

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Introduction

Renewable energy is the term used to cover energy flows that occur naturally and continuously in the environment. The ultimate source of this energy is the sun, gravity and the Earth's rotation [*Warburtion, D 1998*]. These produce energy in many different forms such as hydro, solar, wind, biomass and wave. Harnessing this renewable energy requires large capital investment and in many cases continued research and development. This is the primary barrier preventing the widespread adaption of renewable technology. When compared with conventional fossil fuel technology, renewable energy is expensive, relatively untested and for the most part uneconomical from a developer's point of view. As research and development advances this point of view will change.

However, the benefits of increased penetration of renewable energy are obvious. It is the principal weapon for tackling climate change. Under the European Union's Renewable Energy Directive [*Directive 2009/28/EC. 2009*], Ireland is committed to meeting a target of 16% of energy from renewable sources by 2020. This is a major challenge, requiring a four to five-fold increase in the use of renewable energy. Achieving this has become a key aim for the Government, since doing so will lead to a more diverse, low carbon energy mix, helping Ireland avoid financial penalty by meeting its binding carbon budget and other energy related directives. It will also assist in ensuring security of energy supply while minimising price fluctuation and creating jobs. Ireland has the most energy import dependent economy in the industrialized world, importing almost 90% of all fuels *[Howley, M., D.B.Ó. Gallachóir 2009]*. Taking advantage of the abundant renewable energy sources would reduce the over-dependence on increasingly expensive imported energy while developing new green jobs and investment opportunities at home. Reaching this target will require changes to transportation, power and heat generation. To date progress has been made in both the transportation and electricity generation sectors. Mandatory biofuel obligations of 5% on fuel suppliers and recent tax relief support for biofuels have initiated development in the transportation sector. Ireland has a preoccupation with renewable electricity, with targets for 40% renewable contribution by 2020. Electricity generation from renewables has experienced a four-fold increase in absolute terms, dominated by the growth in wind energy on Irelands windy west coast. This was made possible by a favourable regulatory environment provided by schemes such as REFIT, which significantly increased the financial attractiveness of power generation by wind. However, Ireland must also make significant progress in the thermal sector in order to accomplish the overall renewable target of 16%, since achieving 40% renewable electricity will only contribute to 7% renewables overall. This is a point which seems to escape policy makers, who appear fixated on electricity; the smallest sector of energy usage. As part of Ireland's 16% renewable energy target, renewable technology must account for 12% of total thermal energy by 2020. Based on the energy projections released by the SEI *[Walker, D.N., 2009]* this would require a tripling of renewable thermal usage to the range of 580 - 680 ktoe. There is no single policy or action plan detailing how this is going to be achieved and following current trends would leave us considerably short of our target. At present there are only isolated schemes and programmes which are outlined in chapter 1, which, while aimed at renewable heat, are unfocused, uncoordinated and ineffective. Although a strategic plan from government is due to be published in late 2011 outlining specific plans which will ensure we reach the target, the government are looking at potentially introducing a renewable heat incentive scheme if the scheme is economically viable. Such a scheme has been introduced in other member states and it is detailed further in chapter 1. It is to this end that this research work is being conducted, to answer the question; how can Ireland reach its 2020 RES-H target?

In recent times technologies for the generation of energy from renewable sources are becoming increasingly sought after. Reasons behind this are the increasing fuel prices, environmental issues and issues over security of supply. Ireland depends mostly on fossil fuels for energy, 96% of which comes from fossil fuels and approximately 90% of these fuels are imported. Since such a high portion of Irish fuel is imported the country is open to the effect of the world market. In 2009 the price of a barrel of oil increased to almost $140, this caused the price of petrol and diesel to over increase €1.30/ litre at our pumps and since then has increased to approximately €1.50/ litre. If Ireland wasn't so dependent on imported fossil fuels, crisis's like these would not affect the country as much in terms of our downturn in economic growth presently. Security of supply therefore is a major concern for Ireland. Figure 1 shows the increased dependency on imported fossil fuels since the early 1990's, this increase was due mainly to an increase in population figures and economic growth during the Celtic tiger era.

Figure 1: Shows Ireland's dependency on imported fossil fuel *[Brian O, G., Energy Trends in Ireland, 2009.]*

This thesis details the policies and schemes currently on stream to aid in the successful utilisation of renewable thermal energy to achieve the RES-H target. It also looks at the projections for the RES-H target to 2020 and the many technologies which could bring this target within reach, clearly detailing the potential and barriers of each resource. The renewable thermal energy target is quite complex and will prove difficult to reach as we have to increase our renewable uptake by approximately 10% each year whilst the demand for heat is decreasing.

To reach the target we need to transform our current thermal energy supply making much greater use of renewable sources such as biomass and the utilisation of surplus heat that is presently been wasted. Also, the promotion of electric heating based on renewable generation should be promoted as this would also contribute towards the RES-H target. The renewable sources can be either direct as in the case of biomass, solar and biogas or indirect as in electricity created by wind turbines. We need to introduce a scheme such as the renewable heat initiative schemes in other member states that make it economically and environmentally viable for both large users of heat such as heavy industry and the government, what this means is that the government could pay large users of heat a small fee per kWh of renewable thermal fuel used, such as biomass. This might entice larger users of heat to move away from traditional fossil fuel boilers and retrofit with direct biomass combustion boilers. Widespread use of surplus heat or the adoption of centralised heat production by biomethane or district heating could help Ireland realise its RES-H target. Planning for district heating infrastructure needs to be integrated into local authority development plans, and backed at national level as a strategic priority in urban areas. This thesis concludes with a case study for each of the options applicable to Ireland which should be adapted if we are to meet the target.

Thesis Layout

The layout of the remainder of this thesis shows the background and literature review material in Chapters 1. This includes a look at the policies and targets that are the main drivers of renewable thermal energy and schemes to promote the use of renewable thermal. The current thermal energy situation, rising fossil fuel prices is assessed in chapter 2. The literature review of the various renewable thermal technologies is detailed in chapter 3.

Chapter 4 investigates the technologies appropriate for the supply of thermal energy in the various scenarios. This is achieved through the study of a relevant case study of the technology in operation followed by a calculation of the potential which could be realised by each method. The different scenarios for renewable thermal are:

- Direct combustion of biomass in an urban setting
- Direct combustion of biomass in a rural setting
- Biomethane production in an urban setting
- Non- biomass solutions in an urban setting
- Non-biomass solutions in a rural setting

The conclusion and recommendations are contained in Chapter 5. The conclusions summarise each section and could be read independently. A Discussion and list of recommendations are drawn from the conclusions.

Aims and Objectives

Aims

The aims of this thesis are as follows:

- Consider the implications of the relevant environmental policies and protocols regarding renewable energy in relation to Ireland.
- Gain an understanding of the thermal market in Ireland; its size and energy sources.
- Investigate the renewable alternatives to these sources.
- Investigate the barriers to the renewable alternatives.
- Explore the schemes available to promote the use of renewable thermal energy
- Examine the potential for renewable heat sources; the technology, distribution systems and resources available.

Objectives

The objectives of this report are as follows:

- Identify the technologies suitable for the various options to which renewable heat must be supplied.
- Discover the potential for renewable thermal energy through the utilisation resources available to Ireland.
- Make appropriate recommendations to increase the generation of renewable thermal energy.

Chapter 1:

Energy concerns in Ireland and the rest of the world today:

1. Introduction:

The rising price of fuel in the world today and the constant awareness of climate change and global warming is part of the reason why renewable energy production is crucial to a secure energy supply, especially for Ireland. This worldwide energy problem is further put into perspective below.

1.1 The Energy Problem:

The root cause of world energy problems is growing world population and energy consumption per capita. World population is presently slightly over 6 billion and expected to grow to at least 8-9 billion, and possibly to 12 billion, by the end of the 21st century. It would reach 12 billion by the middle of the 21st century if the present 1.5% per year growth rate were to continue. World economic growth and global demand for energy, the essential engine of economic growth, are expected to grow even faster during the next few decades - by 3.3 percent a year, corresponding to a doubling time of 21 years. How many people can the earth support? Most experts estimate the limit for long-term sustainability to be between 4 and 16 billion. *[Burke, N, 2008].*

The central question addressed is: How can the world meet its energy needs during the 21st century without doing intolerable and irreparable damage to the environment?

1.1.1 Global Energy Consumption:

In 2005, the world's energy consumption of fossil energy carriers and hydro-power was covered by 36% crude oil, 24% by natural gas, 28% by coal, 6% electrical energy generated by means of nuclear and 6% electrical energy generated by means of hydropower *[Burke, N, 2008]*. On a regional level these fractions are strongly dependent on the local and national characteristics due to varying national energy politics or available primary energy resources differing from region to region. Within the time period

1965 to 2005 crude oil consumption rose from about 65 EJ (1965) to approximately 161 EJ (2005).

The quantity of proven oil reserves have been in decline over the past number of year, with a ratio of about 1 barrel in new reserve for every 5 barrels being consumed. As the quantity of oil reserves diminishes, the capacity to extract and consume oil is affected, and has the impact of constraining supply against demand. This has been a factor in recent oil price volatility.

The peak in oil overall world oil production is sometimes referred to as "peak oil" and is illustrated by the scientist M. King Hubbert in a graph of world oil production. This is known as the Hubbert peak theory. *[Burke, N, 2008].*

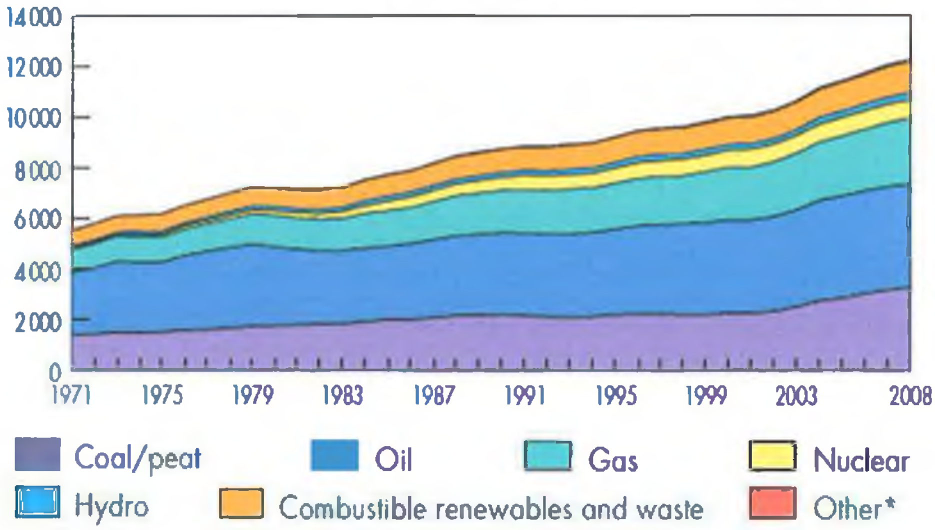


Figure 2: Showing the evolution from 1971 to 2008 of world total primary energy supply by fuel (Mtoe). *[Source: Energy Balances of OECD Countries, 2007]*

1.1.2 National Energy Consumption

On the 12th of March 2007 the Government's Energy White Paper was launched setting out the energy policy directions and targets for Ireland to 2020. It states that "*we live in a world of high energy demand, volatile fossil fuel prices and uncertainty about security of supply*" and that *"energy security and climate change are among the most urgent international challenges". [Dept. of Communications, Energy and Natural Resources, Energy White Paper, 2007]*

1.1.3 Structure of Energy Supply in Ireland

Before discussing the key issues for energy policy it is useful to summarise very briefly some key aspects of Irish energy supply.

Currently the vast bulk of Irish energy comes from imported fuels – coal, oil and gas. The main exceptions are peat and renewables. As shown in Figure 3, these latter domestically sourced energy sources accounted for only a small share of the primary energy used in Ireland in 2009. Once the Corrib gas field comes on stream over the coming decade, a substantial share of the natural gas used will also come from this source. However, the size of the field is such that, without new gas finds, Ireland's dependence on imported gas can be expected to rise again by 2020. Figure 3 below shows Ireland's sources of energy.

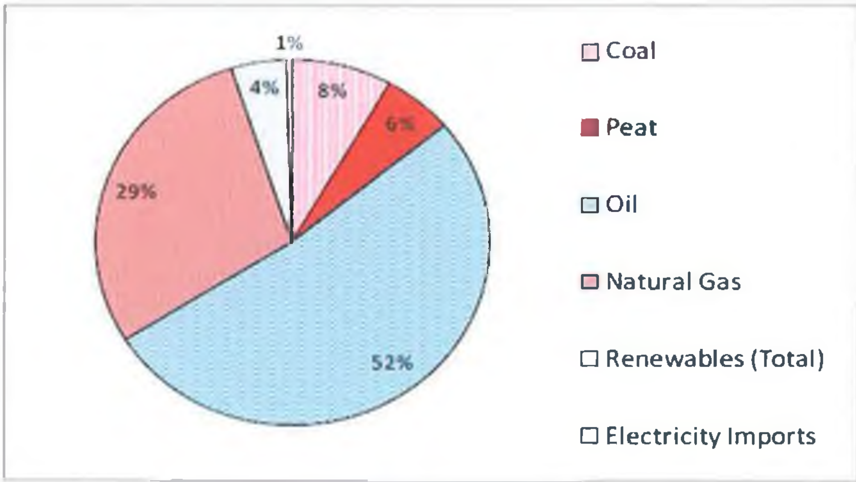


Figure 3: Showing the fuel sources for energy supply in Ireland.

Because of the importance of energy to the proper functioning of the economy, Ireland is very dependent on having readily available sources of supply of oil and gas. Even with some increase in renewables over the coming decade, this situation is not expected to change significantly in the period up to 2020 [Devitt *et al.*, 2010*]*.

As shown in Figure 4, gas and oil accounts for the bulk of fuel used to generate electricity in Ireland. In 2009 almost 57 per cent of all electricity generated in Ireland came from gas. Coal and peat accounted for just over 23 per cent of electricity generated with renewables (including hydro) accounting for just over 14 per cent of the total. Because of the importance of electricity to the running of the economy this makes Ireland very dependent on a reliable supply of gas. *[SEAI, Energy in Ireland, 2010]*

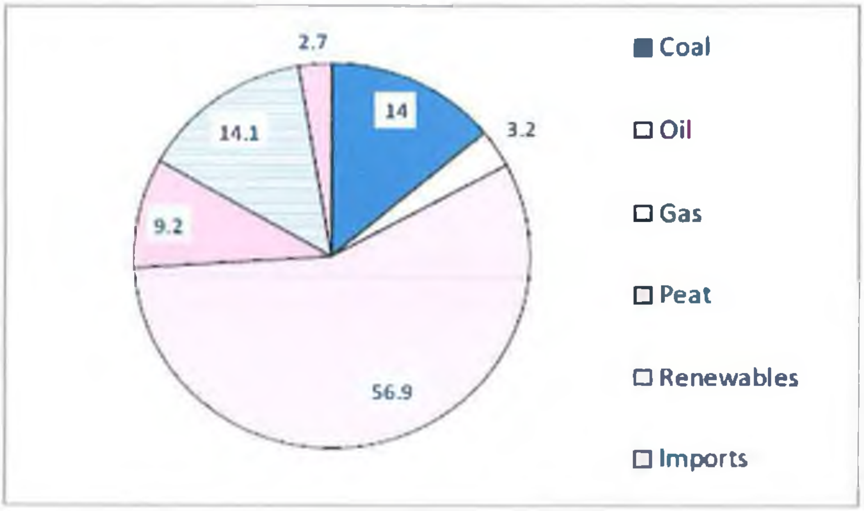


Figure 4: Showing electricity by Fuel, 2009, Share of Electricity Generated by Fuel Used, %. [*SEAI, Energy forecasts for Ireland, 2010]*

1.1.4 Trends in the Irish economy

The second revision of the *Medium-Term Review* (Bergin *et al.*, 2010) explores a number of scenarios for future economic recovery for Ireland and considers the implications of these scenarios for policy, in particular fiscal policy. The two main scenarios considered are: *High Growth* and *Low Growth*. The main difference between the two scenarios is the assumed response of the Irish economy to growth elsewhere. The scenarios assume a modest economic recovery, as it will take time to restore balance sheets. Sovereign borrowing would be higher in the *Low Growth* scenario, and the risk premium on Irish bonds would be higher as a result. The price of peat is projected to stay constant, while the prices of coal and gas will rise modestly with growing demand in the period to 2025. The prices of oil and carbon rise much faster, reflecting tightness in the market and stringent emission reduction targets, respectively. If the Irish economy responds to world economic growth and changes in competitiveness in the same way as it has done over the last twenty years there could be a vigorous recovery over the period 2012 to 2015, as set out in the *High Growth* scenario. Such a recovery would gradually move the economy back towards full employment. On the other hand, the Irish economy could record lower rates of growth over the medium term for a number of reasons; for example, if the export sector has suffered long-term damage, if a continuing high interest premium seriously affects future investment or if structural unemployment remains high due to a failure of labour market policy.

While under such a *Low Growth* scenario there would still be significant growth over the period 2012-2015, it would not be rapid enough to return the economy to full employment. Table 1 shows the key macroeconomic and demographic figures used in this report. It shows levels for 2008, and rates of changes for the periods 1990-2008, 2008-2012, 2012-2020, and 2020-2025. 2008 is the most recent year with complete observations. *[Devitt, C. The Energy and Environmental Review, 2010]*

	Observed		Low Growth			High Growth		
	2008	1990-2008 %	2008-2012 %	2012-2020 %	2020-2025 %	2008-2012 %	2012-2020 %	2020-2025 %
			Real Change Per Year					
Agriculture	4.4	1.6	-0.8	1.0	0.0	-0.8	1.0	0.0
Industry	111.4	8.2	3.1	3.8	0.5	4.8	5.9	1.8
Construction	13.2	4.7	-15.9	6.8	2.4	15.5	7.2	2.9
Services	81.2	5.2	0.2	1.9	1.6	0.6	2.8	2.5
Transport	4.4	6.3	-1.1	3.4	2.3	-0.3	4.4	3.0
Population	4,418	1.3	0.1	0.8	0.9	0.1	0.8	0.9

Table 1: Shows the key macroeconomic and demographic figures used in the Medium-Term Review. *[Devitt, C. The Energy and Environmental Review, 2010]*

Forecasting energy demands to 2020 based on high growth, low growth scenarios.

The ESRI *Medium-Term Review: 2003-2010* (Bergin *et al.*, 2003) published forecasts for the demand for energy over the coming 15 years. The forecast demand for primary energy under different scenarios is illustrated in Figure 5. The solid line represents the Benchmark forecast. However, because of the uncertainty that surrounds the macroeconomic forecasts, a number of alternative scenarios for the growth in potential output were also considered. Here we consider the implications of the scenarios referred to as "High Growth" and "Low Growth" for energy demand. In the low growth scenario primary energy demand would be almost 1 million tonnes of oil equivalent (TOE) less than the benchmark forecast by 2020. In the case of the high growth scenario the Benchmark would underestimate the primary energy demand by over 1 million toe per annum by 2020.

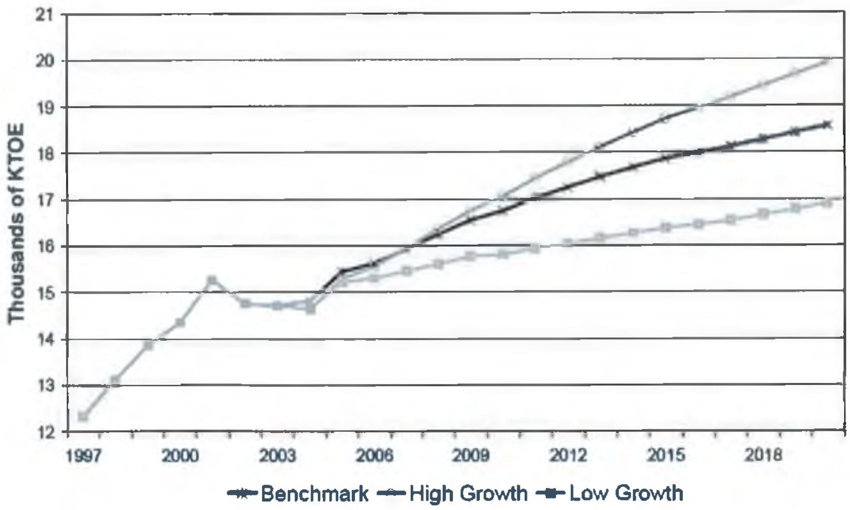


Figure 5: Showing the energy demand for Ireland up to 2020 based on the 'low growth', 'high growth' scenario *[Bergin et al., 2003].*

1.2 Drivers of change

The primary drivers for the implementation of renewable energy in general are environmental, social and economic. The major issues involved are climate change, security of energy supply, stabilising energy costs and employment. Ireland faces similar energy challenges to those of others being confronted worldwide. Our situation is made more acute by our small energy market, peripheral location and limited indigenous fuel resources.

Climate change is arguably one of the greatest environmental threats the world is facing. The impacts and disruption are already being felt today. From 1997 onwards, the world has seen the warmest six years since records initiated. There is a significant risk to global habitats *[Halpin, P.N, 1997]* and extreme events such as flooding, droughts and storms are becoming more and more frequent. The Intergovernmental Panel on Climate Change (IPCC) identifies the following effects of an increase in global average temperature:

- Steady rise in sea level
- Flooding of coastal areas
- Frequent extreme weather conditions
- Frequent poor harvest
- Water shortage
- Loss of biodiversity
- Increase of infections.

The climate change problem is strongly linked to conventional energy use, with more than 70% of the problem attributed to the unsustainable use of fossil fuels such as oil and coal. The challenge is therefore to shift away from our dependency on fossil fuels. This can only be realised through the increased deployment of renewable energy. The natural flow of energy on the planet provides a huge potential for harnessing carbon-neutral energy for society. The big challenge is developing the technology, knowledge and infrastructure in order to achieve this.

1.2.1 Energy Legislation and Policy

- Objectives of energy policy

The overall objective for Ireland in regulating the energy sector was to ensure the lowest possible cost of energy in the long term, subject to a secure supply and subject to meeting the environmental constraints of the various policies. A simplified approach can be made by assuming that policymakers will take as given various environmental and security of supply standards and that, by satisfying these standards, they will then aim to meet the nation's energy requirements at minimum cost. This avoids the problem of having to consider possible trade-offs or conflicts between these multiple tasks. *[J. Fitzgerald, Mary Keeney, Aspects of Irish energy poilcy, 2005]*

The need for state intervention in the energy sector arises for various reasons such as:

1. Energy is a vital part of modern life and the state has an important role in ensuring a secure energy supply, including a secure supply of electricity.

2. The negative environmental externalities that arise from energy production and consumption such as climate change and global warming require state intervention to move the economy in a more sustainable direction.

1.2.2 The Kyoto Protocol

The first major step in reaction to climate change was the Kyoto Protocol *[United Nations, Kyoto Protocol, 1998]* set by the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol is an international agreement between countries to limit emissions of greenhouse gases, the main cause of global warming. The Kyoto Protocol was first opened for signature on 11th December, 1997, in Kyoto, Japan. It came into force on 16th February 2005 after sufficient countries had ratified it. The Kyoto Protocol requires 55 industrialised countries to reduce their greenhouse gas emissions to target levels 5.2% below that of 1990. The six greenhouse gases in question are as follows: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydro fluorocarbons (HFCs) and perflourocarbons (PFCs). Each greenhouse gas is given a global warming potential number which are listed in Table 2. The targets for individual countries vary, with the European Union (EU) target cut set at 8%. Ireland's target is to limit greenhouse gas emissions to 13% above 1990 levels by the period 2009-2012. If unable to reach their target, countries must buy carbon credits from other countries that are under their levels. Developing countries such as China have no requirements under the Protocol. They may sell emission credits and receive funds and technology from industrialised countries for climate-related studies and projects. The time-frame of the Kyoto Protocol is until 2012, with talks on commitments for the post-2012 period on-going, namely the Copenhagen protocol.

Greenhouse gas [4]	Molecular weight	Global warming potential [5]
Carbon dioxide (CO_2)	44	1
Methane (CH_4)	16	21
Nitrous oxide (N_2O)	44	310
Hydrofluorocarbons (HFCs)	34–252	140–11,700
Perfluorocarbons (PFCs)	88–338	6500–9200
Sulphur hexafluoride (SF_6)	146	23,900

Table 2: Showing the gases and their corresponding global warming potential numbers.

The Protocol allows for three mechanisms for countries who are struggling to reach allocated targets to reduce emissions. These are as follows:

➢ An emissions trading scheme known as the Carbon Market which enabled countries that are below their allocated target to trade permits with countries exceeding their allocated target. *[United Nations, Kyoto Protocol, 1998]*

➢ A clean development mechanism whereby a developed country can invest in a emission reducing project in a developing country.

➢ Emission Reduction Credit (CER) which can also be used to meet Kyoto targets. *[United Nations, Kyoto Protocol, 1998]*

Ireland's target under the Kyoto Protocol is to limit its emissions to 13% above 1990 levels or 62.84 million tonnes of CO2 equivalent. Ireland's greenhouse gas emissions and distance to the Kyoto Target are shown in Figure 6 to the year 2007. 2008 data from the EPA puts Irelands CO2 equivalent emissions at 67.44 million tonnes. *[House of Lords European Union Committee, 2008]*. It is clear from figure 6 that Ireland is unlikely to meet its Kyoto target and will have to rely on the purchase of carbon credits to meet its Kyoto commitment which is economically unstable.

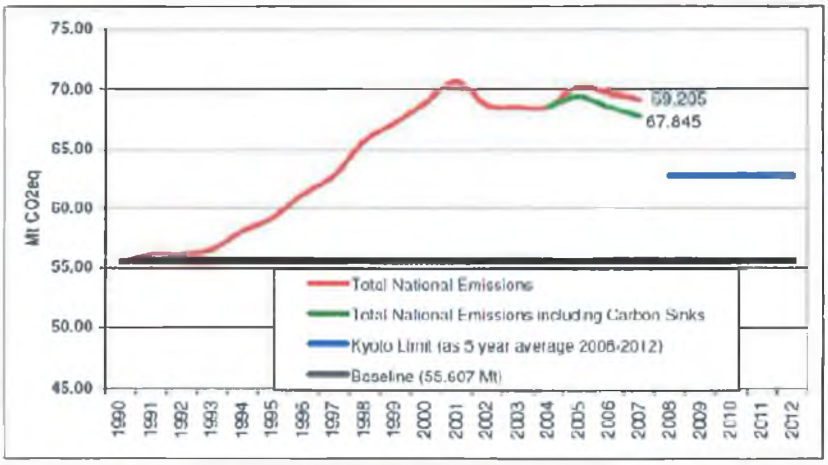


Figure 6: Showing Ireland's CO2 emissions. Source: *[United Nations, Kyoto Protocol, 1998]*

1.2.3 EU Directive 2009/28/EC

The Renewable Energy Directive is an EU energy policy which aims to have 20 % of the EU's energy consumption coming from renewables by 2020. The directive set different targets for each member state with Ireland's target set at 16%. In response to this legislation Ireland has set the following national targets for 2020:

- 40% of electricity produced from renewable sources (RES-E). *[Dept. of Communications, E.and.N.r, 2007]*

- 12% renewable thermal energy (RES-H) *[Dept. of Communications, E.and.N.r, 2007]*

- 10% renewable transport energy (RES-T) *[Dept. of Communications, E.and.N.r, 2007]*

If these targets are met then Ireland should meet its Renewable Energy Directive target of 16% however a report by SEI shown in Figure 7 below predicts that renewable energy will contribute just 7.4% of Ireland's total energy demand by 2020. *[Dept. of Communications, E.a.N.r, 2007].*

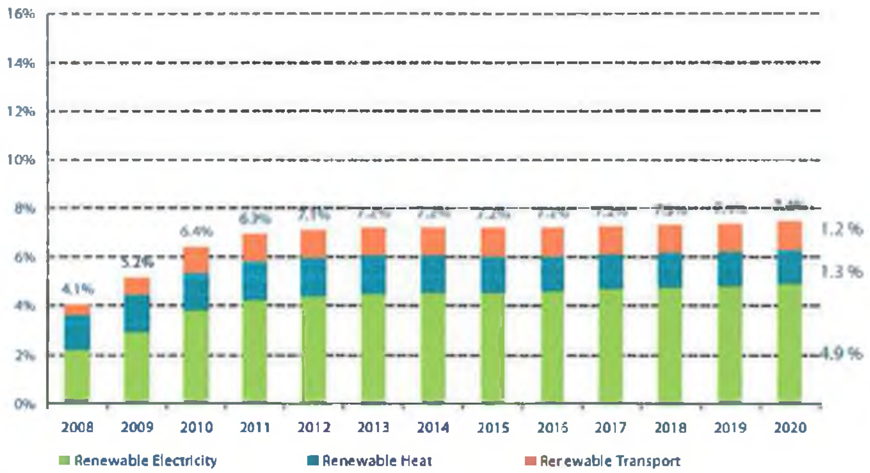


Figure 7: Showing the renewable contribution to Ireland's energy demand.

It is within this context that the EU announced plans for radical renewable energy penetration targets in the Directive 2009/28/EC of the European Parliament and Council of 23 April 2009 on the promotion of the use of energy from renewable sources [*Directive 2009/28/EC. 2009*]. In this document, the EU highlights that the increased use of energy from renewable sources together with energy savings and increased energy efficiency, constitute important parts of the attempt to reduce greenhouse gas emissions and comply with the Kyoto Protocol and with further community and international greenhouse gas emission reduction commitments beyond 2012. The importance these factors have to play in promoting the security of energy supply and providing opportunities for employment and regional development, especially in rural and isolated areas is also acknowledged. This directive replaces the renewable electricity directive (2001/77/EC) and the renewable transport fuel directive (2003/30/EC). The new renewable energy directive (2009/28/EC) sets a binding target for 2020 of 20% of final consumption of energy from renewable sources, with at least 10% of the final consumption of energy in transport coming from renewable sources. The 20% renewable energy target is differentiated across the member states, varying according to GDP per capita. This is illustrated below in Figure 8.

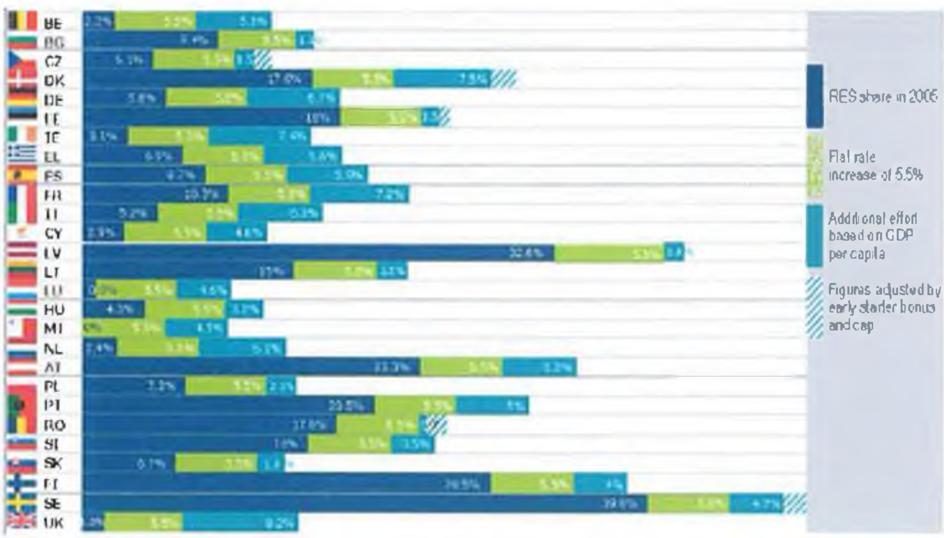


Figure 8: Showing the EU distribution of 20% renewable energy requirement.
Source: [*Directive 2009/28/EC. 2009*].

Irish energy policy is set firmly in the global and EU context and it is from this that Ireland's renewable energy target of 16% is obtained. If Ireland fails to meet one of the specific targets outlined above they may have to increase the output of the remaining renewable energy targets to achieve the overall 16% target.

1.2.4 Energy policy in Ireland (Government's Energy White Paper)

What is the energy white paper?

The Irish Government published a White Paper Directive in 2007 which supplies the action and targets set for energy use in 2020. The following list gives details of the targets set which must be achieved:

- RES-E 33% - electricity from renewables to contribute 33% to gross electricity consumption by 2020 (increased to 40% in October 2008), with an interim target of 15% by 2010.

- RES-H - 12% of thermal energy to come from renewables by 2020, interim target of 5% by 2010.

- RES-T 10% - Renewables to account for 10% of petrol and diesel transport energy by 2020, interim target of 2% by 2008.

The electricity target is the only target which looks most likely to be achieved. Wind energy in this sector is a mature and successful method of injecting renewable electricity energy into the grid. The thermal and transport sector do not look likely of achieving their targets. By 2008 they have only achieved 3.6% and 1.2% respectively. *[Howley, M. D.B.O. Gallachoir, 2009].*

The realisation of these strategic goals is anticipated through policy incentives influencing renewables and bio-energies. The importance of renewable energy is emphasised throughout the document, demonstrated by the national commitments as summarised in

Table 3. It is through delivering these targets that the European directive target of 16% renewable energy in final consumption will be realised. The framework for the delivery of these targets through funding and various initiatives is detailed.

Energy Application	2010 Renewable Target	2020 Renewable Target
Thermal	5%	12%
Electricity	15%	40%*
Transport	3%	10%

*Originally set to 33% but extended to 40% in the Carbon Budget in October 2008.

Table 3: Showing the national targets set out in the energy white paper.

1.2.5 Bioenergy Action Plan

The Bioenergy Action Plan realises the increasing role that bioenergy has to play in the overall security of supply and fuel diversity objectives for Ireland. It sets out an integrated strategy for the delivery of bioenergy resources to help meet the renewable energy targets. Bioenergy has huge potential, especially in the heat sector where biomass, landfill gas and biogases can all contribute to the target. The growth of biomass is considered, reporting that some 141,000 ha of land could be available for growing energy crops. Other sources of biomass for the heat sector are also investigated including forest residues, thinning and off-cuts arising from sawmilling and board manufacture. Policies aimed at expanding the wood energy and renewable heat sectors such as the Rural Development Regulation (2007-2013) are important.

1.3 Support policies for RES-H

Throughout the past few years the Irish government have been supporting renewable heat technologies in the private sector primarily through grant schemes. These are initiating the development of emerging renewable heat technology by directly addressing the high installation costs for individuals and small businesses associated with using greener fuels.

1.3.1 Greener Homes Scheme

The Greener Homes grant aid scheme was established in 2006. It provides financial assistance to individual householders for the installation of renewable heat technology based on biomass, solar or heat pumps in existing homes. The aim of the scheme is to ensure a faster uptake of renewable heating systems with the grant intended to cover 30 to 40% of the initial cost. It will also add security to the sector by providing an approved list of products and appropriate suppliers. The approved products and their associated grant value are listed Table 4.

Technology	Grant Amount
Solar Thermal - Evacuated Tube (per m^2 to a max. of $6m^2$)	€300
Solar Thermal - Flat Plate (per m^2 to a max. of $6m^2$)	€250
Heat Pump - Horizontal ground collector	€2,500
Heat Pump - Vertical ground collector	€3,500
Heat Pump - Water (well) to water	€2,500
Heat Pump - Air source	€2,000
Wood Chip/Pellet Stove	€800
Wood Chip/Pellet Stove with Back Boiler	€1,400
Wood Chip/Pellet Boiler	€2,500
Wood Gasification Boiler	€2,000

Table 4: Showing the greener homes schemes grant levels.

1.3.2 Home Energy Saving Scheme

The Home Energy Saving Scheme allows individual householders of dwellings built before 2006 to obtain grants for investment in energy improvements such as roof and cavity insulation, heating controls and BER assessments. Although similar in nature to the greener homes scheme its aim is reducing the thermal energy demand as opposed to increasing renewable heat technology penetration. The measures covered by the scheme and related grant allowance are listed in Table 5.

Measure	Category	Grant
Roof	Roof Insulation	€250
Wall	Cavity Wall Insulation	€400
	Internal Wall Dry-Lining	€2,500
	External Wall Insulation	€4,000
Heating Controls	Heating Controls Upgrade	€500
	High Efficiency Gas or Oil fired Boiler with Heating Controls Upgrade	€700
BER Assessment	A Before works and an After works BER assessment	€200

Table 5: Showing the Home Energy Saving Scheme grant levels.

1.3.3 Renewable Heat Deployment Programme (ReHeat)

Launched in 2007, the ReHeat Programmes is an addition of the Bioheat Programme. It provides assistance for the deployment of renewable heating systems in industrial, commercial and public premises for the deployment of wood chip/pellet boilers, solar thermal systems and heat pumps. Grants are available up to 30% of the installation cost depending on the size of the project. For example, an industrial scale 500 kilowatt biomass boiler costing in the region of €175,000 would receive a grant of €52,500 under the scheme. Various completed project are outlined shown in Table 6. The scheme has since been abolished mainly due to financial reasons.

Technology	# Completed Projects	Total Installed Capacity
Biomass Boilers	146	72,010 kW
Solar Thermal	125	1,997.7 m^2
Heat Pumps	48	2,255.79 kW

Table 6: Showing the ReHeat penetration to the thermal energy market since its introduction. Source: *[SEAI, 2010]*

1.3.4 Combined Heat and Power (CHP) Deployment Programme

The Combined Heat and Power programme provides a grant for the installation of a CHP unit. The aim is to increase the deployment of CHP by offsetting a portion of the high initial capital cost. These units generate electricity for the installed site and simultaneously allow for the use of the waste heat. Therefore they are ideal for buildings which have a substantial heat load such as hotels, leisure centres, offices or commercial buildings. At present the programme includes feasibility studies to assist investigation into the application of CHP at specific sites and an installation grant for biomass CHP (wood and waste) across all size ranges and for small-scale fossil fired CHP with a capacity ≥ 50kWe and < 1MWe.

1.3.5 Renewable Heat Incentive Schemes

Renewable heat incentive schemes have been introduced in other European member states including the UK. The Irish government are currently developing a similar scheme which is set to be announced in late 2011. The objective of the Renewable Heat Incentive (RHI) scheme is to increase significantly the proportion of heat that is generated from renewable sources and, by encouraging a switch from fossil fuels, contribute towards carbon reduction goals. Policymakers recognise that one of the most significant barriers preventing take-up of renewables is the higher costs of renewable heating technologies, compared with fossil fuel equivalents. Mainly where an organisation wants to install a renewable heating source it is often deemed too expensive. The RHI will compensate for this additional cost, which will help make renewable heating an option for all. Over time, it is expected that the cost of renewables will fall as technologies enter the mainstream, benefit from economies of scale and become more efficient. Ultimately, renewable heat needs to be able to compete on its own without Government support and this scheme is aimed at kick-starting that.

1.4 The rising prices of fossil fuels

The price of crude oil over the last 10 years is shown in Figure 9. This graph shows a steady rise from $15 a barrel in 1998 to a high of $135 in 2008 prior to the recession which saw prices drop to $50 a barrel. REAPs.

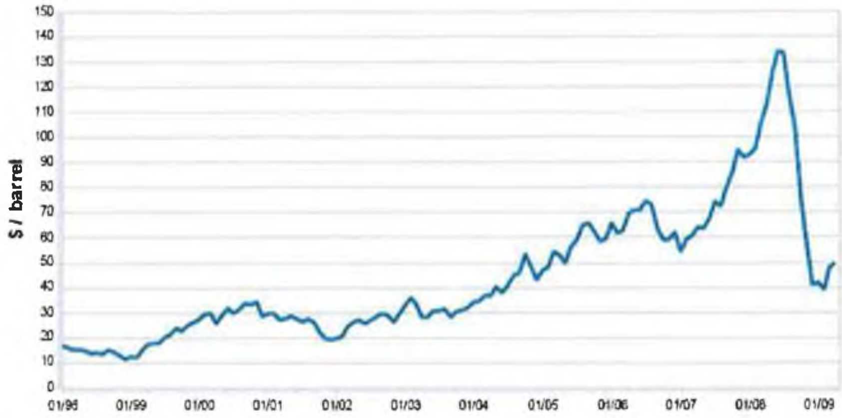


Figure 9: Showing the price of oil per barrel *[International Market for Crude Oil. 2010.]*

A similar trend in natural gas prices can be seen in Figure 10 with the price of natural gas doubling over the last 10 years. This rise in the price of natural gas and oil can be attributed to increased demand from emerging economies such as India and China. High energy prices are undesirable as they stifle economic growth.

Figure 10: Showing the rising price of gas *[International Market For Crude Oil. 2010.]*

1.5 Security of supply

Ensuring a secure energy supply for the foreseeable future is of crucial importance for the health, social and economic welfare of the country. In the case of oil supplies there is limited action the government can take to influence prices and ensure physical security. While very unlikely, physical interruption to supply would have grave consequences. In the very unlikely event of it happening it would affect the entire EU and an integrated response at EU level would offer the best chance of minimising disruption.

Over the coming decade Ireland is likely to become increasingly dependent on gas to supply its energy needs. In particular the bulk of electricity generation will depend on natural gas. This means that any physical interruption of gas supply could have very serious consequences. If such an interruption were to be sustained for more than a few days it could see the island of Ireland lose the bulk of its electricity supply with very serious consequences for the health and welfare of its citizens.

While the chances of a break in an undersea pipeline minimal, if such an event were to occur it would take some considerable time to repair. It is for this reason that the second gas pipeline to Scotland was of major importance to the energy security of this island. The provision of the second pipeline greatly reduces the probability of what was already a very unlikely event. However, the vast bulk of the island's gas supply still goes through a single onshore pipeline in Scotland. As a result, it is important that the supply of gas from the Corrib gas field is brought onshore as soon as possible to enhance the physical security of Irish energy supply. In addition, consideration should be given to strengthening the onshore gas transmission system in Scotland on which nearly all of Irish gas supplies currently depend.

Ireland, along with other developed economies in Europe, faces a much greater risk to its economy from sudden shocks to energy prices than it does from a possible interruption in physical supply. For example, even if there were major disruption in the Middle East, oil supplies would still be available – at a price. However, major price shocks could have serious economic consequences and the regulatory authorities need to consider how best to insure against such future shocks.

As the price of oil and gas are linked, both are likely to rise in real terms and it is desirable to have some diversity in the source of electricity supplies. Keeping this in mind it is crucial that Ireland meets the renewable energy targets set out in the government's energy white paper to further sustain a security of energy to ensure the welfare of its citizens.

Chapter 2:

2. Irish trends for thermal energy.

2.1 The current situation.

The thermal energy market in Ireland is defined as the energy used for space, process and water heating, cooking etc *[Sustainable Energy Ireland, Wood Pellet Stoves. 2008].* It is calculated as the residual energy requirement when energy use from transport and electricity generation are subtracted from the total.
Energy use for thermal purposes accounted for 40% of the total gross final energy consumption in 2008. *[Sustainable Energy Ireland, Renewable Energy in Ireland Update 2010].*

The most recent data available for energy use in Ireland is the figures published by the Sustainable Energy Ireland the SEI report "Renewable Energy in Ireland Update 2010" in May 2010. This report highlights the importance to have a balanced policy for the implementation of renewable technology. Currently the focus has been on electricity, with only minimal attempts to improve renewable penetration in the thermal energy sector. The toe or "tonne of oil equivalent" is used in all graphs and illustrations. This is an international energy measure which allows for a direct comparison of fuel types.

Latest completed figures show that the residential sector accounted for the largest share of final thermal energy use (44% in 2008), followed by industry (33% in 2008), services (18% in 2008) and agriculture (5% in 2008). Oil is the dominant fuel in the thermal energy market accounting for 54% of the primary energy used for thermal purposes in 2008 and this is shown below in Ireland's thermal energy balance. [*Sustainable Energy Ireland, Renewable Energy in Ireland Update 2010].*

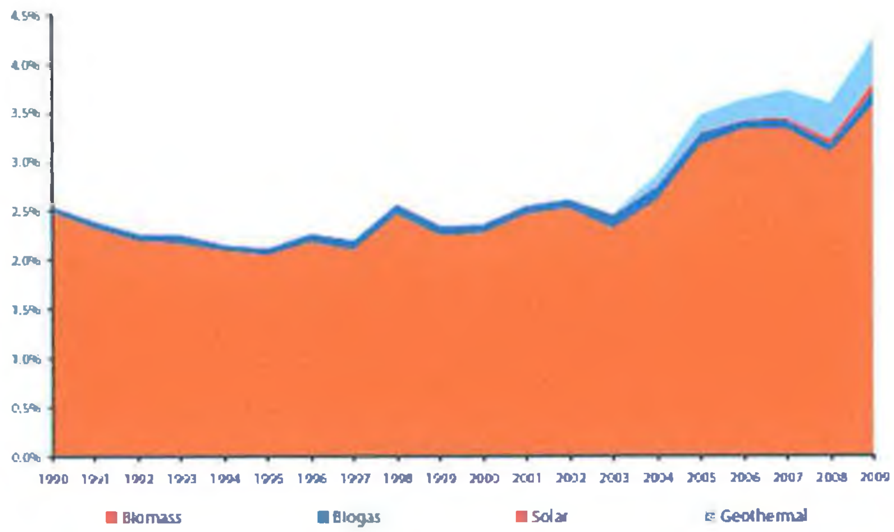
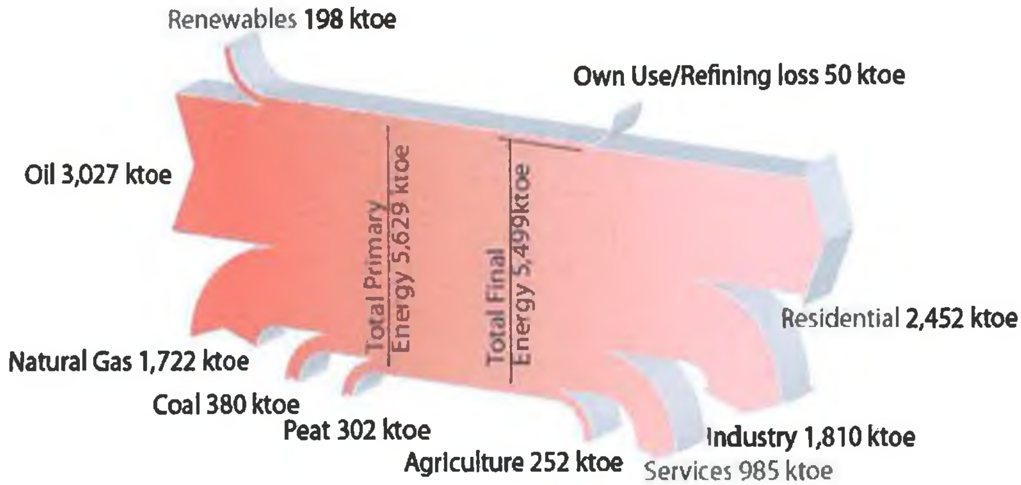


Figure 11: Shows how Ireland currently produces renewable thermal energy *[Sustainable Energy Ireland, Renewable Energy in Ireland Update 2010].*

Renewable energy contributing to Ireland's thermal energy requirements is dominated by industrial biomass use, in particular the use of waste wood to produce thermal energy in fibre board manufacture, joineries and wood processing plants, and the use of tallow from rendering plants for thermal energy. In addition there is a small contribution included in the industry data from biogas generated by anaerobic digestion of food processing waste products.

Figure 12 presents the thermal energy balance in Ireland for 2008. These figures are adapted from "Ireland's Energy Balance 2008". It can be seen that renewables held a 3.6% (absolute value of 198 ktoe) share of thermal energy. In 2009, according to the report "Renewable Energy in Ireland Update 2010" renewables held a preliminary value of 3.9% (absolute value of 258 ktoe) share, representing a 30% growth in the two years 2009 – 2010 or 14% per annum on average.

Also displayed are the sectors thermal use, with residential accounting for the largest share of final thermal energy usage (45%), followed by industry (33%), services (18%) and agriculture (5%).Services include all commercial and public service buildings. This is useful in determining how the 12% target can be met by analysing potential impacts of schemes and policy decisions and prioritising appropriately. From the chart, for example, a scheme aimed at increasing renewable heat penetration in agriculture will have little effect on overall penetration of renewable thermal regardless of the saturation it achieves.



Note: **Some statistical differences and rounding errors exist between inputs and outputs.**

Figure 12: Thermal energy balance for 2008. Source: *[Howley, M., D.B.Ó. Gallachóir, and E. Dennehy, Energy in Ireland - Key Statistics 2009.]*

Source	Quantity (ktoe)	Share (%)
Oil	3,027	53.77
Natural Gas	1,722	30.59
Coal	380	6.75
Peat	302	5.37
Renewables	198	3.52

Sector Use	Quantity (ktoe)	Share (%)
Residential	2,452	44.59
Industry	1,810	32.92
Services	985	17.91
Agriculture	252	4.58
Own Use/Loss	50	NA

Table 7: Shows the latest Thermal Energy Sources and Uses *[Howley, M., D.B.Ó. Gallachóir, and E. Dennehy, Energy in Ireland - Key Statistics 2009.]*

The primary source of renewable heat is biomass, holding an 86% share of renewable fuel stock in 2008, as shown in figure 13. Biomass is an extremely useful and flexible fuel source, ranging from waste woods in industry to wood logs, pellets and chips in the residential and services sectors. Geothermal is the other main contributor, accounting for 10% which is predominantly used in the residential sector with the changes in building regulations with the necessity for a renewable technology. The undeveloped biogas sector which includes the production of biomethane, representing just 2% of renewable heat, is highlighted by these figures.

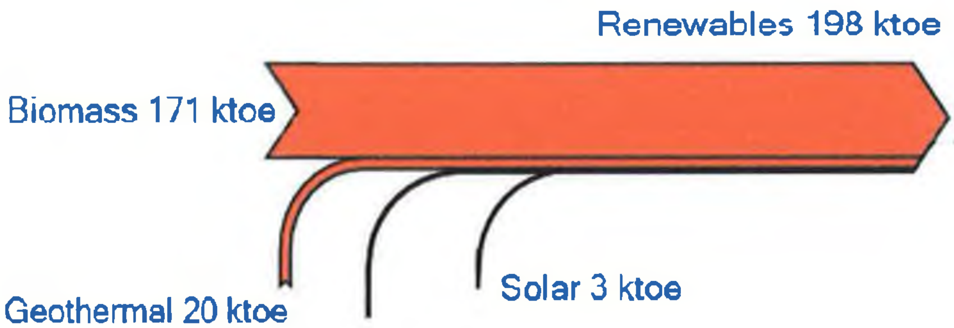


Figure 13: Energy flow of fuel inputs to renewable in 2008

A breakdown of the energy flow for the renewable element of thermal energy, presented in Figure 13 above, clearly displays the levels of usage in the various sectors in Ireland. (Based on the latest completed 2008 figures). Industry dominates with the use of waste wood to produce thermal energy in the wood and wood products industry and the use of tallow from rendering plants in the food, beverages and tobacco industry. Residential usage stands at 22% with renewable thermal in the services area a very recent development. This is shown further in figure 14 below.

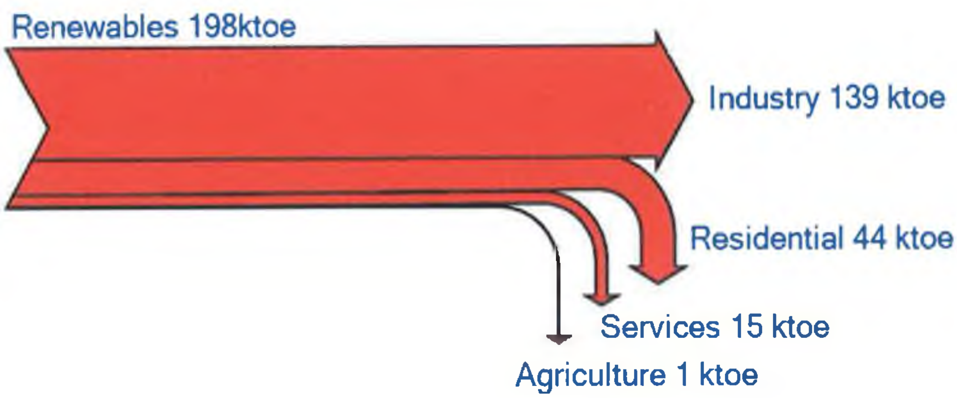


Figure 14: Energy flow of renewable by sector in 2008

The use of renewable heat has been increasing consistently in the previous decade, at an annual average rate of 6% between 1995 and 2008, as shown in Table 8, increased activity in certain sub-sectors of industry and the recent reversal in the decline of renewable heat usage in the residential sector are the principal reasons for this.

	1990	1995	2000	2002	2004	2005	2006	2007	2008
RES-H Sectoral Split (ktoe)	108	92	117	130	146	183	186	185	198
Industry	63	62	100	113	129	163	164	152	139
Food, beverages and tobacco	2	3	4	4	45	54	58	59	41
Wood and wood products	61	59	96	109	84	109	106	93	88
Residential	45	30	17	16	15	17	18	24	44
Services	0	0	0	0	2	3	5	8	15
Agriculture									1

Table 8: Trends in Renewable Energy by Sector [Source SEAI]

Provisional figures for 2009 released from SEAI and contained in the "Renewable Energy in Ireland Update 2010", shows growth in the residential sector for RES-H of 11%. The recent growth in RES-H in the residential sector has also been observed in the services sector, both supported by an SEAI grant scheme called the Renewable Energy Heat Deployment scheme detailed earlier in the chapter.

2.2 Residential

There are two noticeable trends for renewable energy in the residential sector. This sector was traditionally completely dominated by solid biomass (logs) in open fires, but this has decreased in line with the general decline in solid fuel open fires *[Howley, M., D.B.Ó. Gallachóir, 2009]*. The reason for this is the more recent development of "new biomass" in households, such as wood pellet, wood chip boilers, gasifiers and stoves. This has been supported through the Greener Homes scheme explained earlier. This scheme has also seen a dramatic increase in the installation of heat pumps and solar thermal, resulting in the present mix in residential illustrated in Figure 15. Overall this has reversed the declining trend but not is likely to continue as long as funding for the Greener Homes scheme continues to be phased out.

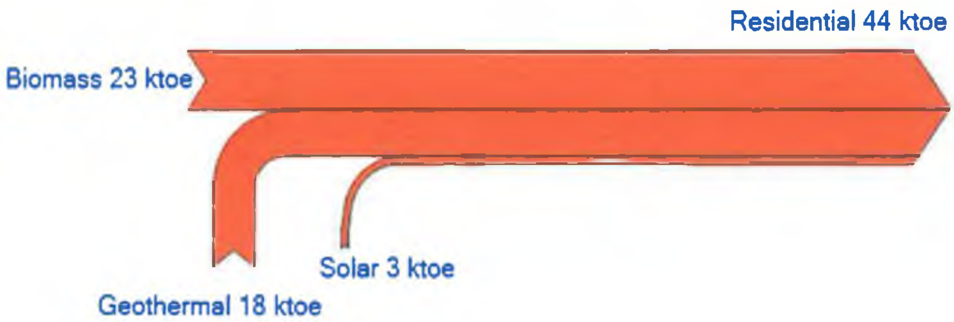


Figure 15: Shows the energy flow of renewables in the residential sector in 2008

2.2.1 Industrial

Industry accounts for 70% of renewable thermal energy, almost entirely supplied by biomass. However, only a small sub-sector of industry makes use of biomass. In addition to this, there is a small contribution from biogas (1 ktoe) generated by anaerobic digestion of food processing waste products.

2.2.2 Services

Recent growth in the services sector is the result of a similar grant programme as in the residential sector, namely the ReHeat programme explained earlier in the chapter. The primary fuel source is once again biomass, the result of a grant supported installation of 72,000 kW of biomass boilers. This is augmented by the production of biogas from anaerobic waste water treatment in the public services sector and ReHeat supported heat pump and solar thermal installation systems as shown in Figure 16 below.

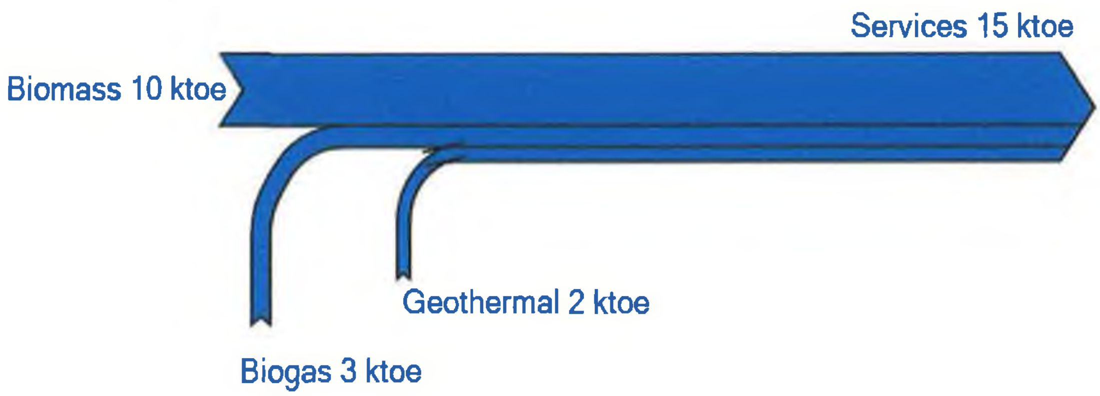


Figure 16: Shows the energy flow of renewable in the services sector in 2008.

2.2.3 Agriculture

The contribution of renewable energy in the agriculture sector is small at 1 ktoe. This is in the form of biomass, generally from the combustion of waste harvest for grain and other drying processes.

2.4 Future

The SEI"s most recent set of energy projections, "Energy Forecasts for Ireland to 2020, 2009 Report" *[Walker, D.N., et al., 2009]* examine the expected trends in thermal energy for this period. Table 9 and Table 10 summarise the results of this analysis, showing the variation in thermal energy depending on the scenario. The "Baseline scenario" acts as a reference for future policies to be measured against. Implicit in the baseline projections are the outcomes of policies affecting both energy efficiency and renewable energy. The "White Paper Plus scenario" builds on the baseline scenario, with additional assumptions to account for the key national renewable energy and energy efficiency measures and targets been achieved. Table 9 clearly shows the required level of renewable heat to achieve the government's 12% target.

	Present (2008) ktoe	**Baseline Forecast (2020) ktoe**	**White Paper Plus Forecast (2020) ktoe**
Final Consumption	13,779	15,243	14,018
Thermal Consumption	5,502	5,718	4,836
RES-H required to satisfy 12% thermal	N/A	687	581

Table 9: Shows the energy forecast for Ireland to 2020

For each scenario, there is a surplus requirement in the region of 600 ktoe, which would represent approximately a tripling in renewable thermal energy usage based on current figures. The significance of this challenge is highlighted in the context of Table 9 above, which shows only a modest increase of 80 ktoe in the past 18 years.

Table 10 illustrates the projected thermal energy uses by sector in 2020. Residential energy intensity decreases as a result of household energy efficiency improvements through retrofitting and the phase-out of low-efficiency (incandescent) lighting coupled with the effect of the 2010 and future 2013 building regulations on new dwellings and the general transition to a low-carbon and passive house standard. The change in industry thermal energy can be linked with the impact of expanded energy savings programmes together with further development of Combined Heat and Power (CHP) and the economic downturn. Services is a distinct area because of the large government ownership of buildings in this sector. The significant reduction in thermal demand expected is linked to achievement of the public sector's 33% energy savings target, as defined in the "National Energy Efficiency Action Plan 2009 – 2020" *[Dept. of Communications, E.a.N.r., Maximising Ireland's Energy Efficiency, 2009],* which provides a reduction of 267 ktoe alone.

	Present (2008) ktoe	**Baseline Forecast (2020) ktoe**	**White Paper Plus Forecast (2020) ktoe**
Residential	2,452	2,501	2,086
Industrial	1,810	2,147	2,098
Services	985	781	450
Agriculture	255	289	202
Total	5,502	5,718	4,836

Table 10: Shows the thermal energy forecast for Ireland to 2020 by sector

According to the White Paper scenario of the energy forecasts published in 2009 by the Energy Modelling Group of SEAI, the thermal energy demand for Ireland would reach 5,160 ktoe in 2010. This suggests that 258 ktoe of renewable energy heat would be required in 2010 compared with 198 ktoe in 2008, representing a 30% growth in the two years 2009 – 2010 or 14% per annum on average, a significant challenge against the context of the recent progress highlighted in Table 11. Provisional 2009 data shows a slight decrease in the amount of renewable heat use indicating a gap to the 2010 RES-H target.

	Growth %	Average annual growth rates %						Shares %	
Renewable Heat	1990 - 2009	'90 - '09	'90 - '95	'95 - '00	'00 - '05	'05 - '09	2009	1990	2009
Overall	**81.7**	**3.2**	**-3.1**	**5.1**	**10.4**	**0.4**	**-1.2**	**4.7**	4.0
Industry Total	105.9	3.9	-0.3	10.1	10.3	-5.6	-6.4	3.3	2.8
Wood & wood products	38.2	1.7	-0.5	10.1	2.6	-6.4	-4.2	2.1	1.8
Other industry	1920.6	17.1	4.6	8.6	65.9	-4.0	-10.3	1.2	1.0
Residential	9.5	0.5	-7.8	-10.4	7.9	18.1	11.2	1.0	0.9
Commercial/Public Services	-	-	-	-	-	41.9	9.1	0.4	0.3

Source: SEAI

Table 11: Shows trends in Renewable Thermal Energy (RES-H) by Sector

Forecasts by SEAI to 2020 estimate a total thermal consumption of 4,931 ktoe in 2020 requiring 591 ktoe of renewable energy in order to meet the RES-H target of 12% by 2020. This corresponds to an average annual growth rate of 10% over the period 2008 to 2020, against the background of growth at 3% per annum on average between 1990 and 2008 and an overall RES-H growth rate of -1% in 2008 and 2009. This indicates the scale of the challenge in the thermal energy sector to meet the renewable target.

Thermal energy demand forecasting is known as one of the most important challenges in managing supply and demand of energy. Consumption pattern of thermal energy has been affected by some social, economical and environmental factors by which the pattern will form various seasonal, monthly, daily and hourly complex variations. Diversity and complexity in consumption pattern of thermal energy have been leading to the extension of already complicated models. Many attempts have been made to find the best estimation for electricity consumption. These studies have been tried to forecast the demand in two levels: (1) Macroeconomic decision making and (2) Engineering and middle management.

Chapter 3:

3.1 Analysis of Renewable Thermal Sources

As shown in Chapter 2, an additional approximate value 591 ktoe of renewable thermal energy is required in the period to 2020. This chapter outlines below, the technologies which could be deployed to achieve this target.

3.1.1 Direct Biomass Combustion

Direct biomass combustion at the point of demand is the oldest form of renewable heat. In Ireland, there has been a long tradition of solid biomass combustion in open fires and ranges. However, this has been in decline in the past decade in line with the general decline in solid biomass influence of energy efficient technologies. This is a trend which is expected to continue as convenience has become an important issue in modern life. The chief area of interest in direct biomass combustion is the emergence of wood pellet and wood chip boilers, gasifiers and stoves.

3.1.2 Biomass Fuel

Biomass is the material derived from previously living organisms, such as trees. It differs from fossil fuels in timescale, with the carbon absorption and release cycle taking place in a number of years. During growth, carbon is extracted from the environment and upon combustion, is released back into the environment as Co2. To be considered sustainable, biomass can only be harvested as part of a constantly replenished crop. Biomass can be divided into three categories:

- Trees: Perhaps the most obvious form of biomass, the wood-fuel is derived from conventional forestry practice such as thinning and trimming.
- Energy Crops: Energy crops are grown specifically for use as fuel and offer high output per hectare. These can range from annual production crops such as willow to longer rotation energy crops such as coppice.

- Wastes and residues: This encapsulates a wide range of biomass materials that are produced as by-products, wastes or residues from other processes such as industry and agriculture. However, only organic quantity of this waste is suitable for combustion.

For reasons of storage, transportation and to aid drying, biomass is pre-processed before combustion with the conversion to chips, pellets or logs. An example of this is shown in Figure 17 below. Biomass stoves and boilers use either wood pellets or chips to allow for the convenience of easy handling and feeding. Wood chips have a low bulk energy density, about 50% of that of solid wood [*The UK Biomass Energy Centre. Wood Chips. 2010]*. Wood pellets are made from dry sawdust compressed under high pressure and extruded through a die *[The UK Biomass Energy Centre. Wood Chips. 2010]*. The low moisture content requirement limits the biomass sources which can be processed to pellets. They may include a low level of added binder to increase robustness. They are more expensive to produce than logs or chips but have the advantage of higher energy content owed to a high density achieved through low moisture content and compression. Therefore they require less storage space than wood chips, increasing their possible application where space is an issue. The various types are shown below.

Wood Logs | Wood Chip | Wood Pellets

Figure 17: Shows the various biomass fuels used in Ireland.

Wood chips and pellets for energy applications must meet an appropriate quality standard if they are to be used reliably in combustion equipment. This involves the control of physical parameters such as maximum size and absence of fines (sawdust), mechanical robustness in the case of pellets, maximum moisture content and levels of contaminants and ash content as these parameters directly affect reliable operation and maintenance schedules. There are a number of established standards for wood pellets in the EU, namely the ÖNORM M1735 in Austria. However, a European standard for solid biomass, including wood chips, is being drafted by CEN 335 which will define these parameters and their acceptance range on a European-wide scale.

3.1.3 Biomass Stoves

Biomass stoves are effectively a modern version of traditional stoves and open fires. They offer the user similar levels of thermal comfort to traditional systems but are highly efficient (90% in comparison to 20-30% for open fires [*Sustainable Energy Authority Ireland, Wood Pellet Stoves. 2008*] and convenient due to the automation offered by a hopper. Stoves primarily use pellets as fuel, which are loaded into a hopper on top of the stove. It is the integrated control system which allows for the increased efficiency and convenience through temperature sensors, automatic on/off timing, accurate combustion air ratio and heat output controls. However, their application is only pertinent to the domestic sector, where they can effectively be used for single room space heating and hot water supply. They are a good option for retrofitting in homes since a direct replacement of existing stoves is possible with a minimum of new pipe work. However, the space requirements for fuel storage would limit the number of dwellings where successful installation could take place, making them only suitable for dwellings in the countryside where the space requirements can be satisfied.

3.1.4 Biomass Boilers

Similar in idea to biomass stoves, they are a direct replacement for traditional boilers. Modern biomass boilers are highly efficient, clean burning and fully automatic making them competitive with traditional oil and gas boilers. However, unlike stoves they are suitable for both domestic and commercial or industrial purposes. Fuel storage is a practical issue, with a minimum recommended storage of 3 tonnes for a typical 15 kW domestic boiler. Automation is achieved through a feeding mechanism (screw / auger) which transports the pellets or chips from the store to the boiler.

On an industrial scale, biomass fired boilers can be used to produce heat or in CHP to produce heat and electricity simultaneously. Implementation of biomass boilers in the non-domestic sector has increased in the past number of years due to government grants. They are now widely used at a small scale (up to 1MW) in hotels, leisure centres, hospitals and schools.

3.1.5 Combined Heat and Power (CHP)

CHP, sometimes referred to as co-generation, is the name given to the energy conversion process where electricity and useful heat are generated simultaneously from a single fuel stream. In other words, it utilises the heat produced in electricity generation rather than releasing it wastefully into the atmosphere. This process yields high efficiencies in excess of 85%, which is directly due to the ability to recover the waste heat energy that is produced during electricity generation. This recovery leads to savings of between 20 – 40% when compared with separate power generators and heat boilers as illustrated in Figure 18.

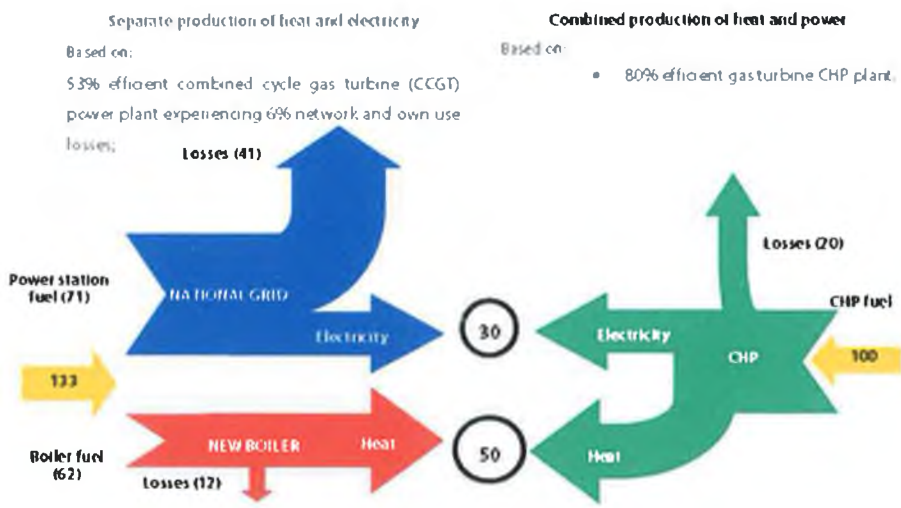


Figure 18: Saving achieved by CHP compared to conventional electricity and heat. *[Sustainable Energy Authority Ireland CHP Policy Group, CHP in Ireland, 2006].*

There is also a large greenhouse gas saving associated with CHP, up to 50% when compared to conventional sources of heat and power, due mainly to the more efficient use of fuel. Gas powered CHP plants are common, but biomass or biogas can also be used. It is through the use of these fuels that the penetration of renewable energy can be increased. Applications of CHP are varied, ranging from hotels, hospitals, commercial buildings, district heating and industrial processes, where a continuous demand for both heat and power exists.

Whether the application is large, small or micro scale CHP, the plant consists of four basic elements.

- A prime mover: A large selection of prime movers are available with the choice depending primarily on the required output, both electric and heat and desired fuel. Table 12 summarises the main types. However, there are also some recent technological advances such as Stirling engines (for micro cogen boilers), microturbines and fuel cells which will broaden the range of applications of CHP, especially on the smaller scale, to even cover domestic installations.

Type	Output Range	Fuels	Heat to Power Ratio	Typical Efficiency	Grade of heat output
Gas Turbine	0.5 MW upwards	Natural gas. Gas oil. Landfill gas. Biogas. Mine gas	1.6:1 up to 5:1 with after burning	Up to 95% with after burning	High
Spark Ignition Engine	Up to 4 MW	Natural gas. Landfill gas. Biogas. Mine gas	1: to 1.7:1		Low and High
Steam Turbine	0.5 MW upwards	Any. but converted to steam	3:1 to 10:1	Up to 90% with gas. 80% with biomass [15]	Medium
CCGT	10 MW upwards	As gas turbine	Down to 0.7:1	As gas turbine	Medium

Table 12: Shows a comparison of traditional CHP generators. *[Combined Heat and Power Association, A Guide to Combined Heat and Power in Ireland. 2004].*

- An electricity generator which converts the torque from the rotating shaft to electricity.
- A heat recovery system, which recovers the heat from the electricity generation exhaust gases. The process is executed by placing a heat exchanger directly after the steam cycle generator and collecting the waste heat. The critical factor is the heat to power ratio demand. Where the electrical power requirement is relatively high as a proportion of the total energy this tends to favour engines, while turbines are superior for high quantities of and higher grade heat, such as steam.
- A control system.

3.1.6 District heating

District heating (DH) is a system for distributing heat generated in a centralised location for domestic and perhaps industrial markets. The origins of district heating systems are intense research and development during times of high energy prices, in particular the 1970"s. District heating was proposed as the solution to expensive fossil fuels for heating by recovering the waste heat from processes such as electricity generation and subsequent distribution through insulated pipes to individual consumers. Recently, the push for Western Nation's security of energy supply has led to an increased focus on CHP using indigenous fuels such as biomass. District heating has numerous advantages over conventional heating systems. By creating the heat in a central location, it allows for the replacement of traditional fossil fuels with biomass. It also leads to lower heating costs, due mainly to the reduced use of fuel. However, there is a large initial cost associated with DH systems, with the construction of a CHP plant and considerable distribution network. This is exacerbated in the case of retro-fitting buildings. According to a report published by the Irish CHP Association *[Combined Heat and Power Association, A Guide to Combined Heat and Power in Ireland. 2004]*, the economics are such that retrofitting for district heating can cost in the region of €2,500 per house whereas new houses can be connected to a district heating scheme for as little as €150 per unit.

The generation of heat occurs at local thermal generation station, usually a CHP plant or a direct heat-only boiler station. However, due to Ireland's underdeveloped heat market, a heat only system is very unlikely. The benefits of CHP for this process are clear, increasing useful energy output of fuel to as high as 90% *[Combined Heat and Power Association, A Guide to Combined Heat and Power in Ireland. 2004]*. This heat is pumped through a network of underground pipes in the form of either hot water or steam to satisfy concentrated heat loads. The distribution system is generally executed through a two-pipe system in closed circulation. Similar to modern domestic central heating systems, the pipes are installed in parallel with one pipe for the supply of hot water to the consumers and the other for the return of water for reheating, as illustrated in Figure 19 below.

Figure 19: Shows a two-pipe DH distribution system [Source: Erich Gasde, http://www.kfw-entwicklungsbank.de]

Typical hot water temperatures are in the region 70 – 120 °C for the supply pipe and 45 – 65 °C in the return pipes. More than 90% of Danish systems operate in this temperature range *[Danish Board of District Heating. Distribution Pipe Information. 2010].* At customer level the district heating is indirectly connected to the central / underground heating system of the dwelling in a thermal substation. Each dwelling has a controls system and metering to allow for temperature adjustment and metered pricing.

3.1.7 Biomethane Grid Injection

A promising option to substitute fossil fuels by renewables is the production of biomethane, as this results in a flexible energy carrier usable via existing infrastructure. Sustainable gas is a combustible gas that can be made from biomass which is upgraded to a quality similar to natural gas. It is manufactured through two main processes; anaerobic digestion of organic (digestible biomass) material, or thermal gasification of organic (waste wood) material. In both cases the synthesis gas produced is upgraded to resemble natural gas in a secondary step and transported and used as such. This option could significantly contribute towards Ireland's 2020 RES-H target. It offers great benefits since a lot of customers can be supplied with renewable energy via the existing gas grid, greatly reducing investment costs associated with district heating. The natural gas used for thermal purposes in 2008 was 1,659 ktoe, which suggests in the region of 25% biomethane in the grid would be sufficient to meet the RES-H target, assuming all injected biomethane is utilised as heat and not in the process of electricity production. Energy losses are negligible during transport and unaffected by scale and distance. This represents a viable option for replacing natural gas in the heat or electricity generation market.

3.1.8 Anaerobic Digestion of biomass

The production of biogas from anaerobic digestion (AD) is an available and commercially proven technology with widespread implementation on both farm and municipal waste treatment scale. In the anaerobic conversion of biomass and waste, organic materials are microbiologically converted to methane, carbon dioxide and water in an oxygen-free environment. Depending on the waste and system design, biogas typically contains 55-75% pure methane *[Hobson, P.N., The treatment of agricultural wastes, in Anaerobic Digestion 1990]*. The liquid/solid fraction can be returned to the ground as a fertiliser. Biogas plants utilising anaerobic digestion therefore make a valuable contribution to the solution of a range of problems concerning agricultural, environmental and energy interests.

Some of the main sources for the production of biogas are sewage treatment plants, landfills and centralised and farm biogas plants. Centralised biogas plants are a mature technology, which have been successfully demonstrated in Ireland on a small scale as outlined in the case study at McDonnell farms in Co. Limerick at a later stage in this thesis. The primary biomass resource is animal manure, which is complemented by other organic wastes depending on what is locally available. The productivity is considerably increased with the addition of this organic waste. Many different types are used, including slaughterhouse waste, waste from the fishing and food industry, etc. Furthermore, an increasing amount of municipal sewage sludge and source separated household waste is used.

The biogas production process is a simple one, in which the biomass mix is pumped into digestion tanks ensuring that natural bacteria are present. It is then decomposed, producing biogas and a liquid element which is used as a fertilising agent. The biomass remains in the tanks for 12 to 25 days depending on the temperature. Thermophilic bacterial digestion occurs at 50-55°C, while mesophilic conditions prevail in the 30-35°C temperature range *[Hagen, M., et al, 2001]*. Thermophilic digestion retention time is on the lower end of the scale with mesophilic digestion needing closer to 25 days for completion. However, new regulations will require a pre-treatment stage if there is food waste, where the food waste is heated at 70°C for one hour before digestion, to ensure complete pathogen kill.

The alternatives, a batch digester and a plug-flow digester are also common on a smaller scale. In the batch digester, all the waste is introduced to the digester at once and the anaerobic bacteria grows and digests the waste. In terms of biogas production, the amount produced resembles a normal distribution curve for the retention period. This varying gas production problem can be overcome by operating numerous digester tanks in one instillation on phased cycles. The main advantage of the batch generator is its simplicity and suitability to digestion of wastes with high solids contents, up to 30 or 40 %, *[Hobson, P.N., The treatment of agricultural wastes, in Anaerobic Digestion 1990]*. The plug-flow digester allows for a through flow of waste without mixing. The tube must be long enough to ensure all the substrate is used up on reaching the outlet. The gas given off during digestion is collected in a similar method to both the continuously stirred and batch flow digesters.

Farm biogas plants operate on a similar principle as centralised plants with slurry the main biomass material and organic waste added to increase productivity. The size and set-up can vary, from steel tanks to concrete basins with various mixing devices. The smaller scale of farm plants usually leads to the biogas being utilised by direct combustion for heating purposes or CHP if sufficient head demand is not present.

Sewage treatment plants produce methane rich gases in the sludge fermentation stage. Collection and utilisation of methane from sewage plants is already widely applied. Optimised system conditions can increase the production and collection of these gases.

Landfill gas is biologically produced from the decomposition of the organic fraction of material in waste deposits (OFMSW). Collection of these gases is via horizontal and vertical perforated pipes by a pressure gradient supplied by a pump or blower. The gas production peaks at approximately 20 years after closure and continues for up to 50 years *[Hagen, M., et al, 2001]*. The extraction of gas also has the added advantage of reduced greenhouse gas emissions to the atmosphere.

3.1.9 Gasification and pyrolysis of biomass

Gasification may be defined as a process by which biomass is converted into gasses by means of a partial oxidization carried out at high temperatures *[Gañán, J., et al, 2010]*, in the range of 600 to 1000 °C. The resulting gas is a mixture of carbon monoxide (CO), hydrogen (H2) and methane (CH4) as the main components that carry the majority of energy in addition to remaining components carbon dioxide (CO2), water (H_2O) and nitrogen (N2) and also a variety of potential contaminants like tars, ammonia, alkalis, etc.

The technology for biomass gasification is mainly derived from the gasification of coal or lignite, which is a worldwide and mature technology. This has brought two main reactor types for use in biomass gasification; fixed bed and fluidised gasifiers. Fixed bed gasifiers are the most suitable for biomass gasification. The biomass is placed into the reactor. During gasification the remaining ashes are removed and new biomass is added. This essentially represents a plug flow system. This is similar to a continuously stirred reactor and only shows partial conversion. However, recycle or subsequent combustion of solids can be used to increase the conversion.

Along with the gasifier dynamics, the gasification agent (air, oxygen, water, steam or hydrogen) and operator conditions such as the temperature and pressure are important. Air is clearly cheap but introduces nitrogen to the biogas which is expensive to remove. The use of oxygen will result in a more CH4 concentrated product gas; however this must be weighed against the expense and energy consumption of an air separation plant. The addition of water (hydrolysis) yields a hydrogen and methane rich product gas and using hydrogen as the agent (hydrogenation) is thought to also improve the product gas. However, both of these methods are at research stage.

Pyrolysis is the chemical decomposition of organic material at high temperatures in the absence of reactants such as water or oxygen. This is an option for biomass because it is readily pyrolysed at relatively low temperatures, starting above 300 °C. In addition to the syngas, this process produces carbon rich liquids and solids. Therefore, gasification of the residual solids and liquids often follows pyrolysis. A recent development is the addition of water to the pyrolysis process. This water is very reactive to the organic material present in the biomass. According to [Hagen et. Al, 2001] these processes hold promise since they can be performed at a small scale, resulting in the use of compact and low cost equipment. The resulting syngas has been shown to contain less inert compounds reducing the cost of cleaning, conversion and upgrading.

After the raw syngas is produced, cleaning is required to remove contaminants. Subsequently the gas enters the CH4 synthesis step (conversion of CO to CH4). Finally, the product gas from the CH4 synthesis is upgraded to meet the pipeline requirements by removal of CO2 and H2O, namely to allow mixing with natural gas for distribution through the existing natural gas system. The general line-up of a biomass gasification SNG system is shown in Figure 20.

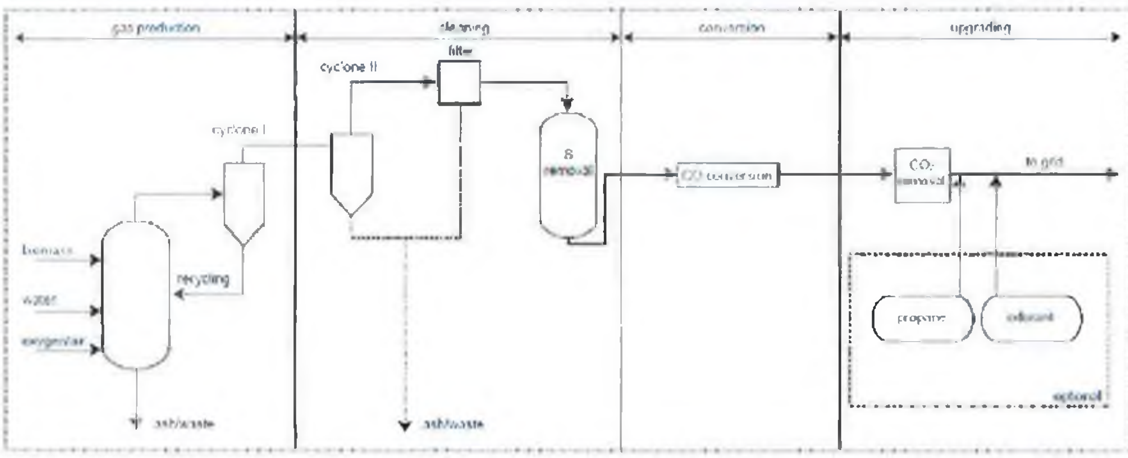


Figure 20: Schematic line-up of the integrated bio-SNG system. Source: *[Hagen, M., et al, 2001].*

3.1.10 Adaption to the natural gas grid

Biogas from anaerobic digestion is primarily composed of methane (CH4) and carbon dioxide (CO2), with traces of oxygen (O2), nitrogen (N2), water (H2O) and sulphur components such as hydrogen sulphite (H2S). Typical composition of different types of biogas and natural gas are shown in Table 13.

Parameter	Unit	Landfill Gas	Biogas Plant	Sewage Plant	North Sea Natural Gas
Lower heating value	MJ/kg	12.3	20.2		47
Higher Wobbe index	MJ/nm^3	18	27		55
Methane (CH_4)	vol-%	45-55	60-70	55-65	87
Carbon dioxide (CO_2)	vol-%	30-40	30-40	balance	1
Nitrogen (N_2)	vol-%	5-15	<1	<1	0.3
Oxygen (O_2)	vol-%	0-5	0	0	0
Hydrogen sulphite (H_2S).	ppm	50-300	10-2000	10-40	1.5

Table 13: Typical untreated biogas and natural gas compositions. Source: *[Persson, M., O. JÖnsson, 2006]*

From a technical point of view, the most important parameter when mixing gases is the Wobbe Index. It is a critical factor in minimising the impact of the changeover when analysing the use of substitute natural gas. Only gases with a similar Wobbe Index can substitute each other *[Jensen, J.K. and A.B. Jensen, 2000]*. It is used to compare the combustion energy output of different composition fuel gases and is defined as:

Equation 1: Calculation of the Wobbe Index

$$I_w = \frac{V_C}{\sqrt{G_S}}$$

Where, I_W is the Wobbe Index

V_C is the higher heating value

G_S is the specific gravity

The energy content of the gas is linked to the methane component, which varies depending on the biogas. Carbon dioxide and nitrogen, which are inert gases, reduce the heating value. Carbon dioxide is always present following AD, whereas nitrogen only appears in biogas created in the presence of air, namely landfill gas. It is the variation in these chemicals and the required removal of other harmful contaminants that necessitates the cleaning and upgrading of biogas.

Cleaning of biogas / syngas

This is the first step in adjusting the biogas / syngas to natural gas quality and involves the removal of components harmful to the natural gas grid, appliances or end-users.
Hydrogen sulphite is poisonous, corrosive and environmentally hazardous upon combustion and subsequent conversion to sulphur dioxide. There are a number of techniques available for its removal, including chemical absorption, membrane separation and activated carbon. Chemical absorption involves reacting the sulphite with a metal ion to form metal sulphite or oxidising to elementary sulphur. Air dosing is also common in plants due to the low costs compared with chemical cleaning and low maintenance. Oxygen is added to the biogas which leads to the biological aerobic oxidation of hydrogen sulphite to sulphur. The chemical reaction is:

Equation 2: Oxidation of hydrogen sulphite to sulphur

$$2H_2S + O_2 \xrightarrow{yields} 2S + 2H_2O$$

The main disadvantage of this method lies in the fact that the required oxygen is usually added as air which also introduces nitrogen to the gas.

Removal of water is required because the raw biogas is normally saturated with water and is accomplished by either separation of condensed water or drying of the biogas. The two most commonly used methods are refrigeration and adsorption. In the refrigeration method, the gas is cooled in heat exchangers and the condensed water forms droplets which are subsequently entrapped and removed. Removing water by adsorption involves utilising a drying agent such as silica gel. However, for continuous operation two containers are required to allow for regeneration of the drying agent.

Other contaminants may be present in quantities which demand cleaning in order to obtain natural pipeline quality gas. The removal of these particles is usually achieved by passing the gas through filters. Ammonia is removed through a washing process with diluted nitric or sulphuric acid, or by activated charcoal units in smaller plants. Biogas from landfills often contains extra contaminants such as halogenated hydrocarbons, organic silicone and oxygen. Snygas must also be desulphurised, usually through the use of activated carbon. The removal of these contaminants leads to lower maintenance costs due to the reduction in corrosion, deposits and mechanical wear *[Persson, M., O. JÖnsson, 2006]*

In terms of snygas produced for gasification, an additional step to ensure the conversion of remaining tars and carbon rich solids to gases and carbon-free ash must be carried out. This is achieved by passing the product gas through a high temperature stage following the initial degradation stage and is often completed in the gasification chamber as part of the gasification stage.

Conversion of syngas

When gasification is used, an extra step is required to chemically convert the carbon monoxide to methane. Both hydrogen and water react with carbon monoxide; the process is described by the equilibrium equations:

Equation 3: Shift conversion of carbon monoxide to methane

$$CO + 3H_2 \Leftrightarrow CH_4 + H_2O$$

Equation 4: Methanation conversion of carbon monoxide to methane

$$CO + 2H_2O \Leftrightarrow CH_4 + CO_2$$

This process results in the removal of carbon monoxide, but an increase in carbon dioxide which needs to subsequently removed in the upgrading stage. At temperatures up to 300 °C a 99% conversion can be achieved. This reaction is highly exothermic but the heat given off can be recycled to dry wet biomass or to help increase temperatures in the gasification process. Without an application for this heat, the energy loss from this stage can be 20 – 30% *[Hagen, M., et al, 2001]*. The resulting gas consists mainly of methane, carbon dioxide and nitrogen.

Upgrading to natural gas quality

The upgrading process comprises the adjustment in calorific value and Wobbe index. This is achieved by separating the carbon dioxide from the biogas / syngas. Furthermore, the gas must be odorised before it is added to the natural gas grid.

Several possibilities exist for the extraction of carbon dioxide. Some of the main methods are detailed below.

- Pressure Swing Adsorption (PSA)
- Water absorption
- Membrane separation
- Cryogenic removal

Pressure swing adsorption utilises activated carbon beds. These carbon beds irreversibly adsorb hydrogen sulphite which must be removed prior to application of PSA. The system comprises four adsorber vessels which operate on an alternating cycle of adsorption, regeneration and pressure build-up. During the adsorption phase, the biogas / syngas is fed under pressure until the adsorption material becomes saturated with CO2.

The gas leaving the top of the adsorber vessel contains > 97% methane *[Jönsson, O., et al. 2003]*. After saturation, the adsorber vessel is depressurised and the trapped gas, which is methane rich, is recycled to the gas inlet. In the regeneration stage a vacuum is applied to the active carbon bed and the CO2 is released. The adsorber tank is then pressurised again before it accepts more raw biogas/ syngas. The process is shown in Figure 21.

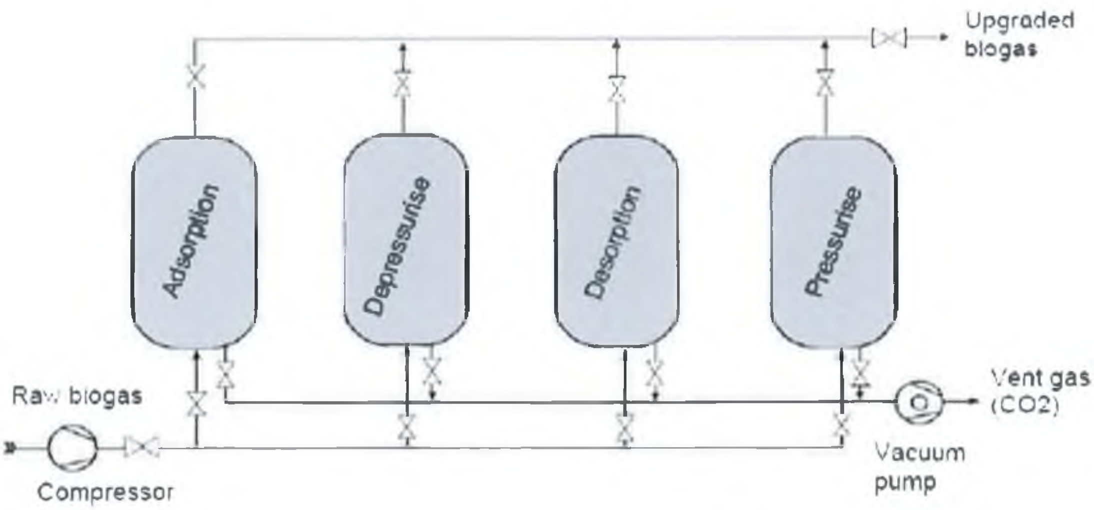


Figure 21: Biogas PSA upgrading system Source: [Jönsson, O., et al. 2003]

Water absorption processes are also known as water scrubbing. Biogas is compressed and fed into the bottom of a column where it meets water. The column is often filled with packing to create a large surface contact area. Carbon dioxide is more soluble in water than methane. The biogas which is brought out of the top of the column is enriched in methane. The water is depressurised in two stages; firstly by a pressure drop to approximately 4 bar which releases dissolved methane and some of the carbon dioxide. This gas is recycled and then the pressure is reduced further in order to release the remaining carbon dioxide. This system operates at approximately 95% efficiency *[Pfeiffer, A.E, 1999]* and is demonstrated in Figure 22.

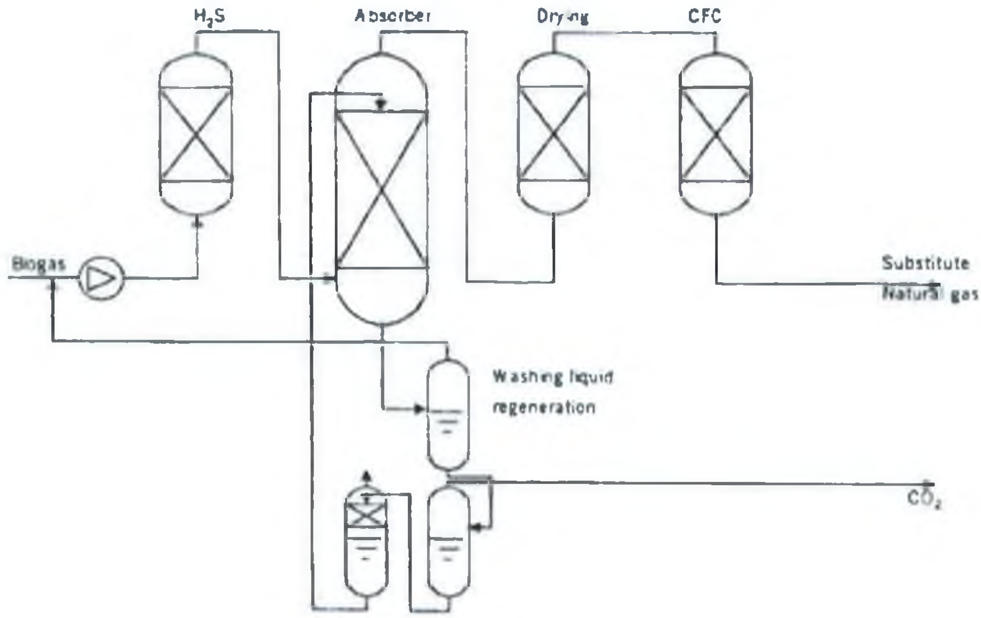


Figure 22: Biogas upgrading system using physical absorption. Source: *[Pfeiffer, A.E, 1999]*

The process is driven by the fact that different molecules (Co2 and H2S) have different permeability through the membrane. Other important factors for the separation are pressure difference between the two sides of the membrane and temperature of the gas. Carbon dioxide and hydrogen sulphide pass through the membrane to the permeate side whereas methane is retained on the inlet side. The concentration of methane in the upgraded gas can be improved by increasing the size or number of membranes, but at a cost of reduces efficiency as more methane will permeate through to the exhaust gas. Efficiency is low, (73 to 83%), energy demand is high (to sustain a pressure of 20 to 35 bar), but the process is relatively simple. *[Pfeiffer, A.E, 1999].*

Carburation, the addition of propane, can be used as a supplementary method of increasing the calorific value and Wobbe index. However, the addition of large quantities of propane is expensive. For Anaerobic digestion gases, a sufficient calorific value can be achieved through the standard cleaning and upgrading process. Therefore, propane addition should be limited to the regulation of gas quality towards pipeline quality standards, compensating for variations in the composition of the upgraded biogas. For syngas, gas produced by gasification, the addition of propane is often required in order to increase the calorific value to a value similar to natural gas.

Odourisation is also required before injection into the natural gas grid to ensure gas leaks will be detected. The same principles and methods which are used for natural gas odourisation are applicable.

3.1.11 Irish Gas Grid

The gas grid in Ireland is extensive, with a national distribution pipeline network of 10,500km and a transmission pipeline network of 2,321km *[Bord Gáis, annual report 2008. 2009]*. The transmission system is linked to the UK and continental markets through two interconnector pipelines with Scotland. Natural gas is available in over 146 areas of high population density, serving almost 630,000 consumers *[Bord Gáis,annual report 2008, 2009]*. The layout of the gas grid is illustrated in Figure 23, where the violet dots are towns in the process of being connected, which will further increase natural gas penetration in the future.

Figure 23: Shows the Irish Natural Gas Grid network. *[Bord Gáis Networks. Natural Gas Pipeline Map. 2010]*.

The natural gas transmission and distribution networks are owned and operated by Bord Gáis Networks, which is a commercial state body operating in the energy sector. Under European council directives for the market concerning natural gas, the gas network, both at transmission and distribution level, must accept biomethane into the network providing it meets the required quality standard.

The benefit of an extensive gas grid now becomes clear since it both provides a large market for the produced biomethane and also allows for a great range of connection points, which should ease any planning and logistical problems associated with biomethane production.

3.1.12 Non Biomass Sources

There are also numerous non-biomass solutions available such as solar thermal, heat pumps, passive design and electrification of thermal supply.

3.1.13 Heat Pumps

A heat pump is a renewable energy technology that extracts heat from low temperature sources (air, water, soil) and upon upgrading to a higher temperature, releases the heat where it is required for space and water heating. They can also operate in reverse to allow for cooling. Therefore, they have the potential to displace some fossil based heating energy. Throughout the world they are primarily utilised in the domestic situation, with the exception of the UK, where the non-domestic sector represent over 90% of the installed capacity. This could be the result of an IEA report *[International Energy Agency, 2002]* in 2002 which concluded that the largest geothermal contribution could be made in the office and retail sector.

A heat pump (when used for heating as is common in Ireland) operates on the same principles as a refrigerator or freezer, but in reverse, as shown in Figure 24 below.

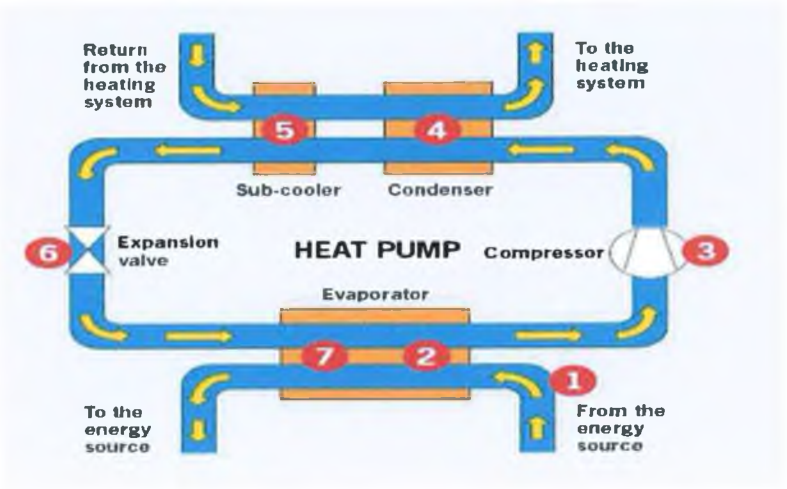


Figure 24: Heat Pump Schematic diagram Source: *[http://www.zenrenewables.com]*

A fluid with a boiling point lower than the heat source temperature, called the refrigerant, acts as a medium for heat transport. As the refrigerant extracts the heat from the source through a heat exchanger, its temperature rises and it evaporates.

- Then a compressor compresses the evaporated fluid. Consequently, the pressure and the temperature of the vapour increase.
- In the condenser heat is transferred from the evaporated refrigerant to the heat distribution fluid (water or air). As it releases its heat, the working fluid temperature decreases to such a degree that it condenses.
- Finally, after passing through the expansion valve, the refrigerant regains its initial low-temperature, low-pressure liquid state. It then flows back to the evaporator where the process starts all over again.

While these systems collect 'free' energy from the environment and deliver it to the house, there is an energy input required. This energy, in the form of electricity, is needed to run the heat pump cycle and to compress the vapour for the production of heat. The ratio of the useful heat delivered by the condenser to the energy used by the compressor is the coefficient of performance (COP) and is a measure of efficiency. The COP of the current generation of heat pumps varies from 2.5 to 5, meaning the thermal comfort of a building can be maintained with a significant reduction in energy input, i.e. for every one unit of electricity, the heat pump provides between 2.5 and 5 units of heat.

The two main types of heat pump are:

- Ground source heat pumps take advantage the heat energy stored in the ground. The temperature of the ground does not vary much over the year which provides a relatively stable supply of heat for the heat pump. The collection pipes can be installed in a horizontal or vertical configuration. The horizontal configuration is cheaper but requires a much larger area per unit of heat supplied. It is suitable for rural residential construction where sufficient land is available. Vertical systems are primarily used for larger buildings to overcome the land requirement problem. Figure 25 shows the installation of a horizontal ground source heat pump.

Figure 25: Shows a ground Source Head Pump Collector Source: *[http://buildipedia.com]*

Water source heat pumps use open water as the low temperature heat source. Large savings on installation costs can be realised due to the comparatively small collector surface area required. However, water temperature is more variable, meaning the required heat may not be available when it is needed.

3.1.14 Solar Thermal

Solar thermal technology extracts energy from the sunlight and utilises this energy in order to raise the temperature of water, through a heat exchanger, located in the hot water cylinder. This water is then primarily used as domestic hot water (DHW), although in some cases it can also be utilised for space heating.

There are two distinct types of collector; flat plate collectors and evacuated tube collectors. The basic principle of operation of a solar collector is that sunlight enters the panel and is absorbed by the absorber. This absorbed heat is then transported and utilised in the building. In the flat plate collector, the absorber is at the back of the panel, with a glass cover allowing sunlight to enter the panel. The glass subsequently prevents the heat from the sunlight leave the panel in the same way a greenhouse operates. As with any system, there is an associated efficiency, affected in this case by both optical and thermal losses. The optical losses include both refraction and absorption of the glass cover and is generally constant for specific cover materials irrespective of temperature. The thermal losses; convection, conduction and radiation are temperature dependent and increase with increasing temperature difference across the panel. A typical cross section of a flat plate panel with indicitative losses is illustrated in Figure 26 below.

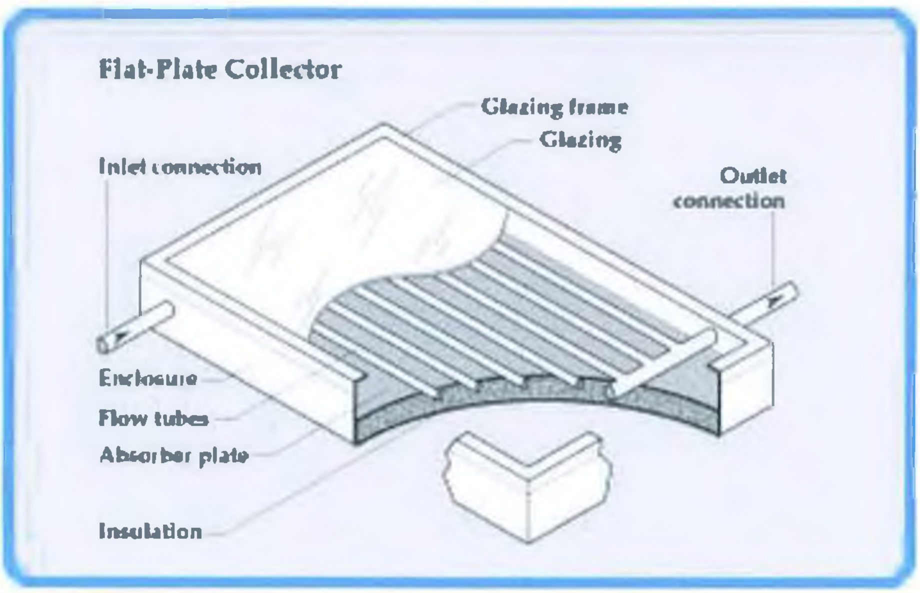


Figure 26: Typical flat plate collector cross-section. Source: *[http://www.suntrader.co.uk]*

Evacuated tube solar collectors (ET) consist of a long tube which maintains a vacuum. Encapsulated in this vacuum is a copper tube, shown in figure 28, containing a volatile fluid which evaporates when heated and in so doing the vapour rises and transfers the heat to a condenser located at the top of the collector as shown in figure 29. Here the heat is transferred to a solar fluid, which subsequently transfers the heat to the hot water storage via a similar closed loop heat exchanger as the flat plate model. The condensed volatile fluid flows back down the tube under gravity and is available for the cycle to be repeated.

Figure 28: Copper tubing of Evacuated tube (ET)

Figure 29: ET Condenser

3.1.15 Decarbonised Electricity

Another option to increase renewable penetration in the heat sector is decarbonising electricity and using this to produce heat. This entails either making much greater use of renewable electricity sources or heating from low or near decarbonised electricity. Decarbonised electricity can be produced from either fossil generating plants fitted with carbon capture and storage or from renewable electricity such as wind and wave.

Renewable electricity sources have been explored extensively with the technology for individual sources at differing levels of maturity. At present, wind is the most economic choice and has experienced massive growth in Ireland in the past decade with a current installed capacity of 1,565.85 MW between Northern Ireland and the Republic. *[Irish Wind Energy Association, 2010].*

By incorporating the heating sector into the electricity sector, the continued expansion of wind could be facilitated. Nuclear is an unlikely option in Ireland, even with the increasing effect on demand of electrifying heat. In late 2008, the ESB stated "nuclear power was unlikely to be on the agenda for at least another 25 years. Carbon capture and storage is based on capturing Co2 from large point sources such as fossil fuel power plants and storing it by a variety of means.

3.1.16 Demand Side Management

A demand-side management approach is central in an overall energy strategy, resulting in the enhancement of energy efficiency and management of buildings and processes so that less heat is lost to the environment. Reducing the overall thermal demand will also help Ireland to meet its 2020 RES-H target since the absolute required increase in renewable will not be as great. Considering the importance of energy efficiency, the Government has established ambitious targets of 20% across the entire economy by 2020 and an individual higher target of 33% efficiency savings for the public sector. The Government has already initiated several programmes to promote energy efficiency and management measures at both a household and business level. These include revised building regulations and the activities of SEAI; mandatory Building Energy Rating Certificates, Home Energy Saving Scheme, the Greener Homes Scheme and the ReHeat Programme. The details of these schemes have been discussed in chapter 1.

Greater use of decarbonised electricity has the advantage of using existing electricity transmission and distribution infrastructure and fits well with existing policy to decarbonise electricity. Low or zero carbon electricity may be a useful form of heat for modern, well insulated buildings. Also, electricity can be used to power technologies like ground and air source heat pumps which provide more energy and warmth than the electricity they consume. The capital cost of electrical heating is relatively low at the point of use, for example in the form of domestic electrical heaters. However, a large scale expansion of electric heating would create significant system costs. For an Irish dwelling, electricity currently accounts for around 23% of the houses total energy load *[Walker, D.N., et al, 2009]*. If all energy including that for heating and producing hot water was electrically sourced, the electricity supply would need to increase several-fold. Increased demand for electricity on this scale nationally would require significant expansion of generation and distribution capacity. There are challenges in substantially increasing the use of electricity for heating related to both the volume of supply required and to seasonality.

3.1.17 Passive house design

Passive construction is an extension of low-energy design and in contrast to energy-efficiency retrofitting is applied to new buildings, especially dwellings.

A passive house describes a house which uses minimal energy for heating, lighting, etc. despite being of a similarly high level of comfort to conventional dwellings. In passive house standards, the heating requirement is reduced to the point where no central heating system is required. The basic principles of the idea are:

- Minimise heat losses. This is achieved by sealing the house with a thick layer of insulation as well as highly insulating windows. Construction to passive standards requires a maximum U-value of 0.13 W/m²K, which is less than half of the current building regulation *[Building Regulation 2008, 2008]* maximum U-value of 0.27 W/m²K.The U-value of a material is a measure of its insulating property.

- Maximise free solar energy: The second aim of solar architecture is to allow as much sunlight into the house as possible, achieved by giving the house a southerly orientation and locating larger windows on the south facade. According to an SEAI report on passive solar design [SEAI, *Passive Solar Design*. 2005, SEAI.], an East-West house orientation results in a 15% increase in space heating demand compared to a Southern orientation.

- In a highly insulated and air-tight house, replacing indoor air regularly without excessive heat loss is important. Mechanical heat recovery ventilation systems are usually employed to maintain air quality and also to recover sufficient heat to provide hot water or preheat incoming air.

Applying these design processes results in a building which required much reduced levels of thermal energy to maintain adequate comfort levels.

Chapter 4:

4.1 Options for Ireland

4.1.1 Introduction to each option

After completing the initial research part of the thesis, it was clear that any target is unlikely to be met through one solution alone, but rather a combination of strategies and policies that are targeted for the different circumstances for which renewable thermal will be required. In the earlier part of the thesis, key areas of development for the implementation of renewable heat were outlined. Five options have been developed to allow for the implementation of the all the technologies identified. These options are presented in the following Sections and are described in this Chapter.

4.2 Direct Combustion

Perhaps the most obvious solution to the provision of renewable thermal energy is the direct combustion of biomass. A wide variety of materials are suitable for use in biomass combustion. Sustainable forestry operations and specially grown energy crops could make as substantial contribution as wood waste, grass, straw and so on. Both domestic applications for heating purposes and large-scale power plants for heat and electricity production with the utilisation the heat through district heating are possible. Direct combustion in rural and urban locations are put into further perspective below.

4.2.1 Rural Areas

In Ireland, there has been a long tradition of solid biomass (wood logs) combustion in open fires and ranges. However, this has been in decline in the past decade in line with the general decline in solid biomass and is a trend which is expected to continue as convenience has become an important issue in modern life. The chief area of interest in direct biomass combustion is the emergence of wood pellet and wood chip boilers and stoves. This can work with the existing heat distribution systems such as underground heating, radiators and hot water cisterns already present in the dwelling, allowing for a minimum of disruption during installation.

The large space needed for fuel storage is not a critical parameter in this environment, which allows for the wholesale purchase of fuel ensuring the system is economic. Developing this sector further will be a key prerequisite for meeting renewable energy targets in the future. This chapter looks at direct combustion in the rural setting by demonstrating the technology through a case study. The potential for direct combustion of biomass is then analysed through a study on the availability of feedstock; forestry, waste wood and energy crops, both currently and potentially available.

4.2.2 Urban Areas

Direct biomass combustion in the urban setting focuses on the large scale combustion and subsequent distribution of heat through a district heating system. By creating the heat in a central location, it allows for the replacement of traditional fossil fuels with biomass which would otherwise be unlikely due to space restrictions in high density housing and apartment complexes. Higher efficiencies can be expected in the centralised combustion units than in individual boilers while eliminating the need for operation and maintenance by the customer. District heating can be installed economically when included at the design phase of either new development or regeneration projects. However, it is expensive it retro-fit existing buildings due to the expense and inconvenience caused by the associated construction and installation necessary pipework. Its use is widespread throughout Europe and it provides an effective route to market for the waste heat from electricity production. In this sense its growth in Ireland is seen as essential in helping to satisfy renewable thermal targets. This chapter demonstrates the successful application of the technology and details the plans for future district heating, especially in Dublin.

4.3 Biomethane

A promising option to substitute fossil fuels by renewables is the production of biomethane, as this results in a flexible energy carrier usable via existing infrastructure i.e.

the natural gas pipeline infrastructure. Biomethane is a combustible gas that can be made from biomass which is upgraded to a quality similar to natural gas. Its primary focus would be the delivery of renewable thermal in the urban setting via the existing gas grid, greatly reducing investment costs associated with district heating. Energy losses are negligible during transport and unaffected by scale and distance. Furthermore, the end-user will see no technical modification and existing administrative procedures used for green energy could also be applied because of their similarity. This represents a viable option for replacing natural gas in the heat or electricity generation market.

4.3.1 Urban

Delivering renewable heat to dwellings, industry and commercial buildings in an urban setting is a challenging task. Biomethane injection into the gas grid offers a unique opportunity to significantly contribute to Ireland's RES-H targets. It can be delivered via existing gas distribution infrastructure and there will be no requirement for consumers in domestic and non-domestic applications to make alterations to their individual heating system, due to the existing dense gas network in the urban areas of Ireland. Anaerobic digestion or gasification of biomass at a few central locations close to the biomass source is advocated since distribution losses within the gas grid are not an issue. This would remove any logistical issues associated with transporting and storing large quantities of biomass in towns and cities. Therefore, biomethane injection to the gas grid has the potential to provide a large-scale solution for renewable heat. This chapter looks at biomethane production and subsequent natural gas grid injection by demonstrating the technology through that of case study.

4.3.2 Rural

Biomethane is produced from anaerobic digestion of wet biomass or gasification of solid biomass. In this chapter, the author looks at injection into the natural grid and subsequent utilisation in individual dwellings and premises in the major towns and cities which are connected to the natural gas grid. However, in areas not connected to the gas grid, an opportunity exists to produce biomethane and either supply it in a specially constructed town gas network or to a CHP plant from where the heat produced could be utilised.

4.4 Non-Biomass

The non-biomass options are also discussed, with a focus on heat pumps and solar thermal; technologies which provide an alternative source of thermal generation. Both can be utilised in either an urban or rural setting. However, domestic scale heat pumps are usually limited to situations where there is space for a horizontal collector.

4.4.1 Rural and Urban

The focus of non-biomass sources of renewable thermal energy in a rural locale is heat pumps. Heat pumps extract thermal energy from the ground, thus making them useful for heating applications. They are particularly appropriate when incorporated with a low temperature heat delivery system such as under-floor heating as this increases the efficiency of the system. The application of heat pumps for this use is widespread throughout the world. This chapter demonstrates another use of the technology, in a large-scale commercial situation with a case study of the heat pump system in the Lewis Glucksman gallery.

4.5 Direct Combustion Rural

4.5.1 Introduction

This option recognises that renewable gas is not the one and only solution to the renewable heat issue. Various technologies will need to be adapted to succeed in meeting the target as there are certain situations, especially in the rural setting, example, off the gas-grid, where alternative solutions are more preferable. The options for renewable heat in this circumstance are varied with biomass combustion showing the most promise. Retro-fitting of heat pumps and solar thermal in dwellings is ineffective unless the building is sufficiently thermally insulated; only contributing a small portion of the heat requirement. Heap pumps have a very high associated capital cost unless a water source is available to allow for an open loop design. This has the added complication of fishery and Environmental Protection Agency (EPA) regulations relating to water quality and interference to fish. The most obvious solution to providing renewable heat is through the installation of biomass boilers and stoves. This can work with the existing heat distribution systems such as underground heating, radiators and hot water cisterns already present in the dwelling, allowing for a minimum of disruption during installation. The large space needed for fuel storage is not a critical parameter in this environment, which allows for the wholesale purchase of fuel ensuring the system is economic. Developing this sector further will be a crucial step for meeting renewable energy targets in the future. This chapter will look at a successful project in operation in Ireland, the woodchip boiler installation at Kelly's Hotel. Through the study of this project, the application of the technology will be explained.

4.5.2 Case Study – Kelly's Resort Hotel

A technical, economic and environmental will be carried out for the woodchip boiler installation at "Kelly's Resort Hotel" in Rosslare, Co. Wexford. The hotel comprises 117 bedrooms and suites, three restaurants, two bars, two indoor swimming pools, steam room, sauna and 1400m² spa complex. The heating system retrofit occurred in early 2006.

Technical Analysis

Kelly's Hotel Site

The hotel made a conscience decision to become more environmentally friendly and significant work has been done to affect this in recent times. All rubbish from the hotel is now fully source-separated with the recyclables collected and sent to the local recycling centre. With capacity for over 1,000 meals per day, the considerable organic waste is separated and composted on site.

The heating system prior to the biomass boiler installation consisted of three 150 kW oil fuelled boilers. This is the typical situation for many dwellings and businesses which are off the gas grid. The installation of a biomass boiler was aimed at reducing energy costs and improving the environmental impact of the hotel. Also, energy efficient lighting has been installed in the hotel as part of their aim to reduce their energy costs.

Feedstock Preparation

The fuel source for the biomass boiler is woodchip, primarily due to economic reasons. One of the main technical considerations of switching from oil to biomass was the space requirement for woodchip storage since there is little free space on site. This challenge was overcome by locating the fuel store, a 70 m² prefabricated shed, on top of a flat roof on an existing building at the hotel. This holds approximately 14 tonnes of woodchips, sufficient to provide for over a week's supply at continuous full output. The woodchip is delivered weekly from a nearby sawmill and is blown up to the store. From here, the boiler system is fully automatic with augers transferring the woodchip to the boilers

Plant Description

Following analysis of the heat requirement of the premises based on past oil consumption, a 350 kW woodchip boiler was installed which is sufficient to meet the base load for the site, representing 90% of total thermal demand throughout the year. In addition to the lead biomass boiler, two of the three existing 150 kW oil boilers remained in-situ, only becoming operational if the woodchip boiler is offline or to meet peak loads in extremely cold weather. Essentially the oil boiler is used as 'back-up', to the newly installed woodchip boiler.

The steam produced in the boiler heats water in two 3,000 litre tank, from where it is drawn to supply the domestic hot water and space heating demand of the hotel, swimming pools and spa.

System Appraisal

Economic Analysis

The capital cost of the completed project totalled €104,880, with a €26,220 grant secured from Sustainable Energy Authority Ireland (SEAI) through the Renewable Heat Deployment Programme. The heating fuel costs, presented in Table 14, clearly show the annual savings which are benefited by the hotel.

2005 Heating Fuel Costs		
Fuel Consumption	**Fuel Type**	**Total Fuel Cost**
143,238 litres	Oil	€76,229[1]
2006 Heating Fuel Costs		
Fuel Consumption	**Fuel Type**	**Total Fuel Cost**
323 tonnes	Woodchip	€25,840
46,762 litres	Oil	€25,356
	Total	**€51,250**
Annual Fuel Cost Savings		**€24,979**
Payback Analysis		
Total Project Cost		€104,880
SEI Grant		€26,220
Annual Fuel Cost Savings		€24,979
Payback Period		3 years[2]

Table 14: Shows an economic Analysis of Kelly's Resort Hotel (Source: SEAI)

With the SEAI grant of €26,220, taken into account, the remaining €78,660 capital investment will have a payback period of three years. When fully operational, the estimated woodchip demand is 488 tonnes annually. At a cost of €80/tonne, this indicates woodchip fuel costs of €39,040 coupled with €7,622 on oil, leading to fuel savings of €29,567. Taking this into account, the actual payback period is a very respectable duration of three years. The short payback period is one of the reasons why the hotel decided to change the heating system.

Environmental Analysis

The environmental advantages are realised through switching the primary fuel from oil to carbon neutral woodchips, with the CO2 equivalent emissions reduced by 90% as derived in Table 15.

2005 Heating Fuel Consumption

Fuel Consumption from Heating Fuel	Fuel Type	Total Emissions
143,238 litres	Oil	362 tonnes CO_2/yr

2006 Fuel Consumption

Fuel Consumption from Heating Fuel	Fuel Type	Total Emissions
323 tonnes	Woodchip	0 tonnes CO_2/yr
46,762 litres	Oil	130 tonnes CO_2/yr
Reduction in CO_2 Emissions		**252 tonnes CO_2/yr**

Table 15: Shows the Environmental Analysis of Kelly's Resort Hotel (Source: SEAI)

Conclusion

The biomass boiler installation at Kelly's hotel has proved to be a very successful application of this technology. Only in operation for four years, the system has already paid for itself and will continue to profit the hotel, safeguarding it from high costs in the oil market as supplies decrease. Also the installation of the new boiler will have the decreased the carbon footprint and improved the Building Energy Rating value of the building. By switching the thermal energy supply fuel from oil to woodchip, a saving of 344 tonnes/year of carbon dioxide is achieved. Additional rollout of this technology must be encouraged further, especially in the commercial and residential sector through rural and small town Ireland where space permits.

4.5.3 Application to Ireland

Thermal Demand

The estimation of the thermal demand which could be satisfied by direct combustion is quite simplified. It is assumed that industry and commercial thermal demand is proportionate to residential since figures for their demand per region are not easily available.

Fuel Source

As detailed in chapter 3, the fuel for direct combustion is wood logs, chips or pellets. Ireland has a limited potential for these fuel sources, with a small percentage of forestry covering and restrictions regarding agriculture land which can be utilised as arable land.

Forestry

Forestry and solid wood will provide the main source of solid biomass for the foreseeable future in Ireland through the use of:

- Sawmill residues
- Pulpwood
- Forest residues
- Construction and demolition wood waste
- Wood packing waste

Energy Crops

Energy crops are a type of renewable fuel which may be defined as plantations grown specifically for the purpose of producing energy from the harvest. The main types of crop in this category are summarised below. The main factors regarding energy crops are the yield produced, suitability and sustainability of the growth. The major energy crops applicable for growth in Ireland are:

- Willow
- Hemp
- Miscanthus

The production of energy crops requires the use of arable land, which is limited in Ireland to 400,000 ha by the Cross Compliance Directive *[Directive EC 1782/2003, 2003]*. From the available 400,000 ha, only 293,300 ha were utilised for food production in 2009 *[Central Statistics Office, CSO, 2009]*, a decrease of 20,400 ha on the previous year.

4.5.4 Direct Combustion Urban

Introduction

The next major option for the delivery of renewable heat is through direct biomass combustion. There are two chief areas of interest here; direct biomass combustion is the emergence of wood pellet and wood chip boilers and stoves and the indirect supply of heat through the centrally located CHP and subsequent distribution through a district heating system. Primarily due to space restriction, the potential for district heating is the focus of this chapter. District heating can be installed economically when included at the design phase and its use is widespread throughout Europe. Its major advantage is that the heat utilised is essentially free, the waste product of electricity generation from CHP.

4.5.5 District Heating in Ireland

The potential for district heating in Ireland has been present for a long time without being acted upon because many stakeholders are involved in the development of a district heating network and high initial investments have to be made without the certainty of a large customer base. Recent developments in the Irish district heating market suggests that there is a shift away from fossil fuel based supply, but with the building of new properties presently at an all time low, Ireland may have has missed its chance to incorporate district heating on a large scale. At present there is a relatively low number of small scale systems operating or under development:

4.6 Case Study: Dublin District Heating Project.

Introduction

Development of a district heating system in Dublin City was first considered by the ESB in 1981/1982. Although the subsequent report concluded that such a scheme would be "technically possible and would be very advantageous to the Irish society, the utility and the individual", it did not result in the development of a district heating system.

The recent interest in a district heating system for Dublin stems from similar factors to renewable energy; that of sustainability and economics in the face of climate change and rising fossil fuel costs. However, the condition placed on the planning approval for the thermal waste treatment facility in Poolbeg which will require it to be designed and configured to allow for the supply of heat to a district heating network *[McCormack, I. and C. Miller, 2010]*. Following this, Dublin City Council commissioned a feasibility study on the potential for the implementation of a citywide district heating network.

Heat Source

As mentioned earlier, the primary reason for development is the availability of a major inexpensive heat source. Initial thermal output from the "Waste to Energy" facility is expected to be 90 MW (thermal) increasing to 150 MW (thermal) when the plant is fully operational. This has the potential to supply the annual average heating requirements of 60,000 homes through the installation of a district heating network *[McCormack, I. and C. Miller, 2010]*.

Heat Market

The district heating scheme in Dublin will initially focus on areas of regeneration; the Docklands and Heuston Area, since enabling district heating in new development is considerably cheaper than retro-fitting existing structures. This will connect a wide range of customers to the network including residential, commercial and industrial. In the longer term, a major contribution is envisaged from public buildings and hotels, including local authority buildings, universities and hospitals, encouraging a wide variety of results in a more balanced heat load and level peak demand.

Feasibility Study

The feasibility study; "District Heating for Dublin" published in July 2008 *[Gaillot, O., et al, 2008]* considered three alternatives for the citywide district heating scheme:

- **Scenario 1 – Dublin Docklands:** This is a concentrated district heating network focusing on the Dublin Docklands Redevelopment Area.

- **Scenario 2 – Westgate:** This considers a smaller independent district heating network in the St. James" Gate / Heuston Area. The heat supply in this scenario includes the excess heat from the Guinness Brewery CHP and peak and reserve boilers at St. James Hospital and Heuston South Quarter, totalling 85 MW (thermal)

- **Scenario 3 - Citywide District Heating Network:** This district heating network links the networks in scenario 1 and 2 in a route following the Liffey. It will supply all heat consumers in scenario 1 and 2 together with planned heat consumers south of the river Liffey in the areas between Westgate and the Docklands

4.6.1 Results

The results of the environmental and economic analysis are presented below in Table 16. It clearly shows that a district heating scheme utilising waste heat from power generation will be competitive with traditional natural gas heating. This is highlighted by the fact that all three scenarios considered show an acceptable payback period. Construction of the district heating network will allow for the utilisation of a major renewable heat source, the Poolbeg Waste to Energy plant, which can contribute 91.6 ktoe of RES-H. This is the primary supplier of heat in both scenarios 1 and 3 and the effect of incorporating this renewable heat source can be seen in the significant carbon savings for this case.

	Scenario 1	Scenario 2	Scenario 3
Area	Dublin Docklands	Westgate	Scenario 1 & 2 and area between
Connection Period	2008 – 2010	2010 -2020	2008 – 2024
Total Heat Load (MW_{th})	79	84	285
Heat Consumption (MWh)	111.000	107.000	300.000
Network Size (km)	7.8	4.2	30.5
Total Investment Million €	21.5	14.9	55.9
Payback	8 years	9 years	10 years
Accumulated Result Million €	61.8	10.8	132.8
Internal Rate of Return – 20 years	15.4%	8.4%	17.5%
Internal Rate of Return – 10 years	7.5%	-4.4%	2%
CO_2 Savings (tonnes)/year	12,000	-5.000	32.000
Toe saved/year	9.500	-	28.000

Table 16: Shows the proposed Dublin District Heating Feasibility Study Results *(Source: DublinWasteToEnergy.ie)*

4.6.2 Application to Ireland

District heating is a mature technology and is employed extensively in mainland Europe, especially Eastern Europe and Scandinavia as Table 17 demonstrates this.

Country	Penetration (2007)
Austria	18%
Croatia	9.5%
Denmark	29%
Finland	49%
Germany	13%
Iceland	93.9%
Latvia	28.7%
Netherlands	3.6%
Norway	4.7%
Poland	47%

Table 17: European Countries District Heating Penetration. Source: *[Euroheat & Power]*.

District heating has not had the same penetration in Ireland for a number of reasons. Ireland's relatively mild climate does not help the economics of installation on a large scale. Low density of housing even in cities makes it impractical to pump warm water over long distances. It has also a poor public perception and is sometimes seen as "poor man's heat". This is due to its image as being of low quality in terms of reliability and control. This may have been the case with old district heating systems such as previously operational in the Ballymun flats located in Dublin, but newly installed or upgraded systems overcome these problems by allowing dwellings individual control over temperature and by having separate conventional boilers to deal with peak loads in very cold weather.

According to a report, "A*n Examination of the Future Potential of CHP in Ireland"*, by the Sustainable Energy Authority Ireland in 2001 *[SEAI, CHP in Ireland, 2001]* quantified the potential for district heating in Ireland. 100MW was 'technically' feasible and 50MW was feasible against 'economic' criteria. When this, now conservative CHP to district heating projection is coupled with the likely contribution from the proposed Dublin scheme along with a proposed scheme in Co. Cork, a renewable thermal contribution of 53.363 ktoe is could be achieved from district heating in 2020, helping us to meet the white paper target.

4.7 Biomethane Urban

4.7.1 Introduction

Delivering renewable heat to dwellings, industry and commercial building in an urban setting is a challenging issue. Most of the discussion on renewable heat to date has been focused of heat pumps, solar thermal and biomass boilers. None of these options are particularly suitable for the introduction of renewable heat to existing urban areas. As mentioned in earlier chapters, biomethane injection into the gas grid offers a unique opportunity to significantly contribute to Ireland's RES-H targets. It can be delivered via existing gas distribution infrastructure and there will be no requirement for consumers in domestic and non-domestic applications to make alterations to their individual heating system as the gas is upgraded to natural gas standard. Massive upgrading over the last 10 years has resulted in a dense gas network in the urban areas of Ireland.

The expense and inconvenience caused by the construction of district heating is its major disadvantage and makes it unsuitable for the provision of renewable heat in existing buildings. The space and specific geological conditions required for successful application of heat pumps means only a small contribution to renewable heat is envisaged. Direct biomass combustion in boilers suffers from the logistical problems associated with transportation and on-site storage of the large quantities of wood chips/pellets in a situation where space is minimal. Also direct biomass combustion removes the opportunity for the extraction of valuable chemicals such as lignin and lactic acid which can be removed through the application of "white technology". In this sense, anaerobic digestion or gasification of biomass at a few central locations, preferably close to the biomass source since distribution losses are not an issue and injection into the gas grid would remove these issues. Therefore, biomethane injection to the gas grid has the potential to provide a large-scale solution for renewable heat.
This section investigates the technologies capable of producing biomethane; anaerobic digestion and gasification. The case study focuses on Anaerobic Digestion. The application of biogas upgrading is then examined with its potential contribution to the thermal supply determined.

4.8 Case Study: McDonnell Farms Biogas Limited

McDonnell Farms Biogas Limited is a company which owns and operates an Anaerobic Digestion Plant at Dunmoylan, Shanagolden, Co. Limerick. The Plant processes digestate from a poultry and dairy farm as well as other imported feedstuffs. The resultant electricity produced is sold to the national grid and the heat generated recycled for heating of the plant and the nearby poultry enterprise. The farm is located near the current natural gas network and could potentially supply biogas to the national grid. The processed digestate is used on local farm land as a fertiliser.

Anaerobic Digestion (AD) is the process whereby organic matter is broken down by bacteria and enzymes in an oxygen-free environment. The organic matter is then released as biogas; this is a mixture of the combustible gas methane (50-75%), carbon dioxide (25-45%), small amounts of water (2-7%) and trace gases. This process occurs in bogs, landfill and in the stomachs of animals and then the biogas can then be upgraded with the intention of injecting the biomethane in the natural gas grid.

4.8.1 Technical Analysis

McDonnell Farm Site

The site is located in Shanagolden, Co. Limerick. During 2009 and 2010, Limerick farmer David McDonnell installed one of the most advanced anaerobic digestion (AD) on-farm plants in the country. David milks 300 dairy cows and runs a medium-sized free range poultry farm with his brother Richard. As well as the digester they have recently installed two 2.3 MW wind turbines which were connected to the grid towards the end of 2010.

Plant description

The feedstock is pumped into a closed vessel (digester) which has been inoculated with suitable bacteria. Anaerobic (0% oxygen) conditions are then maintained in the vessel and the temperature is held at a constant value (typically 40°C). The type of feedstock used by anaerobic digesters varies; it can include pig or cattle slurry, food waste, energy crops and municipal solid waste from households and organic solid waste from industry.

Plant components:

- Reception hall for liquids and semi solid waste including, disinfection unit, feeding and storage tank 200 m³
- Reception area for on farm animal by-products (slurry, poultry litter) and sludge's
- Primary-digester and first covered storage tank 980 m³ net (17 x 6m) insulated and covered with double layer foil
    - Integrated gas- and mechanical mixing systems (agitators)
    - Integrated progressive cavity pump
    - External heat exchanger to heat feedstock
- Covered storage tank 2,500 m³ net (26 x 6m)
- Separator to separate digestate in liquid and fibre
- Biological gas cleaning, gas cooling, gas analyser
- CHP unit: MAN, 250 kW (electricity). 263 kW(thermal).
    - Approximate efficiency rates: 38% electrical, 41%, Thermal (integrated heat exchanger)
- Full automation of the plant

The system is illustrated below in figure 30.

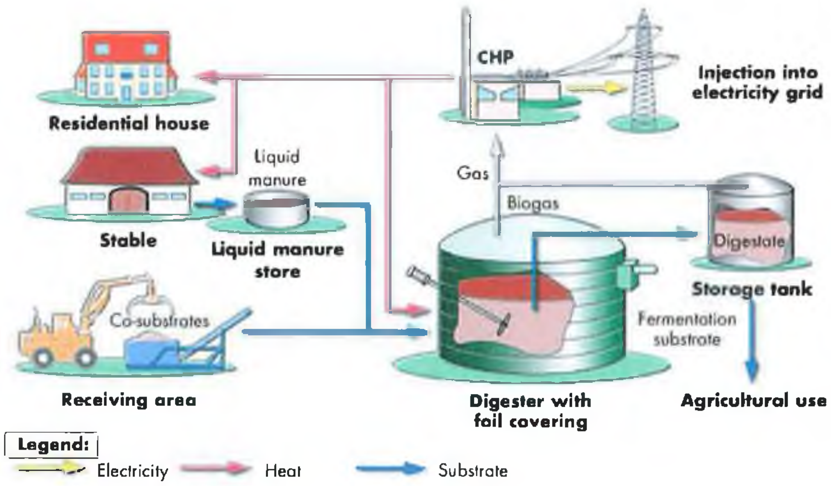


Figure 30: Shows the plant layout at the McDonnell Anaerobic Digestion facility. Source: *[McDonnell's Farms Biogas Ltd]*

Feedstock:
Cattle slurry: 5,800 tonnes/annum, (10% dry matter content)
Food waste: 2,800 tonnes/annum (22% dry matter)
Poultry litter: 900 tonnes/annum (40% dry matter)
Dairy sludge: 900 tonnes/annum (22% dry matter)
Glycerine: 360 tonnes/annum (90% dry matter)
Sum: 10,760 tonnes/annum

Table 18: Shows the feedstock and quantities used at the Biogas plant. Source: *[McDonnell's Farms Biogas Ltd]*

The biogas produced can be upgraded to natural gas (fossil) quality as explained earlier in the previous chapter and injected into the gas grid. The biogas yield depends on the composition of the feedstock and on the ambient conditions in the digester (e.g. temperature, retention time). It is possible that the same feedstock could have different gas yields. For example 2 kWh electricity and 2 kWh heat can be produced from 1 cubic metre of biogas depending on the CHP unit and gas composition used (e.g. 55% CH4 content in the biogas, 20 MJ/m^3, 38% electrical and thermal efficiency CHP unit).

The residue or digestate of the AD process can be separated into a liquid and fibrous fraction. The liquid is returned to the land as a high value fertiliser and the solid fibre is used as a soil conditioner. Biogas technologies contribute to environmental protection as they release no carbon dioxide (Co2). Energy from biogas is largely Co2 neutral because the Co2 released from burning biogas was already removed from the atmosphere through photosynthesis.

Economic Analysis

Below in table 19 and table 20 the economic performance of the Anaerobic Digestion facility at present is shown. It highlights the fact that at a REFIT price of 15c/kWh, the production of renewable energy is economically viable, with costs showing much lower than the income. The lifespan of the project is assumed to be 15 years with all other assumptions detailed in the calculations.

Output of the plant:
Availability CHP unit: ~91%; 8,000 full load hours/annum
Biogas production: ~950,000 m³/ annum (55% CH4 content, 20 MJ/m³)
Electricity production: ~2,000,000 kWh/annum, mostly exported to the national grid
Heat production: ~2,100,000 kWh/annum, this is heat exported for heating the plant, for pasteurisation and for heating the poultry sheds, heat could also potentially be injected to the natural gas grid.

Table 19: Shows the electrical and thermal output of the plant

Economic and Environmental Appraisal
Primary energy savings: ~1,200 MWh/annum
CO2 savings: ~1,500 tonnes CO2/annum
Total capital cost: ~ €1.5m
SEAI CHP grant: €108.000
Payback time: approx. 10 years
REFIT: 15 ct/kWh exported electricity

Table 20: Shows an economic appraisal of the Biogas plant

4.8.2 Conclusions

The Anaerobic Digestion system at the McDonnell farm site has been described above. The system has many social, economic and environmental benefits over the generation of electricity by conventional fossil fuels. The use of slurry and food waste allows the system to operate more economically through fuels savings from displacing high price electricity and heat.

In the case of the farm located in Shanagolden, the biogas plant will produce electricity and heat constantly for 8,000 hours per year, which means in the region of 2,000,000 kWh of electricity and 2,100,000 kWh heat. The electricity will sold to the national grip for an increased price under the REFIT scheme. They will receive 15 cent/kWh of electricity being exported. The heat is going to be used in the plant itself, for the pasteurisation and on farm for heating the poultry sheds to replace fossil fuels. The potential to export heat to natural gas grid will also exist, should a connection to the natural gas grid be developed from the site.

4.9 Application to Ireland

The production of biogas from AD has been adopted widely throughout Europe, with over 3,500 digesters currently in Germany. However, their main purpose at present is electricity or CHP, where the biogas is burned on site to produce electricity which is exported to the grid. The production of biomethane should be considered as this results in a flexible energy carrier not subject to distribution scale and loss issues. It also presents a solution to the electricity grid connection issue which, due to its high cost, has proved a deterrent to the Anaerobic digestion process in Ireland. The fuel source for anaerobic digestion plants is agricultural slurries, sewage sludge, industrial wastes and organic fraction of municipal solid waste (OFMSW). Ireland has a considerable potential for these organic wastes, especially agricultural residuals such as slurries and slaughter house waste due to the high intensity of farming in Ireland along with the landfill directive which aims to divert food waste away from landfill sites. A report by Singh et. al. *[Singh, A., B.M. Smyth, and J.D. Murphy, 2009]* details the total quantity of energy available and the practical energy available via anaerobic digestion from the agriculture sector in the period to 2020. This energy availability is calculated based on levels of slurries available for digestion and the construction of facilities to enable treatment of slaughter house and tallow waste and is summarised in Table 21 below.

	2007	2010	2020
Agricultural Slurries (PJ/a)	16.94	16.52	15.53
Slaughter House Waste (PJ/a)	1.52	1.43	1.37
Tallow (PJ/a)	1.59	1.48	1.44
Total Potential Energy (PJ/a)	20.05	19.43	18.34
Practical Energy Potential (PJ/a)	0.15	1.423	3.275

Table 21: Shows the energy potential of the agriculture sector. Source: *[Singh, A., B.M. Smyth, and J.D. Murphy, 2009].*

Landfill gas also has the potential to play an important part in the production of biomethane, with five landfills currently developed to recover landfill gas. At present the recovered gas is converted to energy in the form of electricity. Heat is also produced during the recovery process, but no markets exist near the landfill gas stations. The total feasible electric power from all of Ireland's landfills is 304.7 MW (electricity) *[Irish Energy Centre, 2001]*. The current electric capacity from the five existing plants is 15 MW (electricity), this clearly illustrates the potential for development in this area. However, landfill gas provides only a medium term source of biogas since it is dependent on the decomposition of biodegradable wastes which go to landfill. From 2016, under the "National Strategy on Biodegradable Waste" *[Dept. of Environment, H.a.L.G. National strategy on waste, 2006]*, published in April 2006, 65% of biodegradable waste must be diverted away from landfill. This will result in reduced landfill gases leading to reduced biogas production, lessening its potential to play a major role in the production of biomethane.

4.10 Non-Biomass Urban/Rural

4.10.1 Introduction

Heat pumps are the main consideration in this category. Heat pumps are primarily applicable in two situations; horizontal collectors for dwellings and vertical or open-loop collectors in commercial and industrial applications. However, the one major obstacle to increased heat pump penetration is their unsuitability to retro-fitting because they are not readily compatible for conventional heating systems, with entails water circulating in the radiator system at temperatures of 60 – 90 °C. They are, however suited to under-floor heating which can easily be incorporated at the design stage of new buildings. This is due to the lower delivery temperature of 25 – 45 °C and associated reduced electricity required to produce this lower temperature water. Commercial applications usually require a much larger thermal supply, eliminating the utilisation of the significantly cheaper horizontal collector. In this case, the alternatives are vertical or open-loop collectors. Although these options are more expensive, this option can prove very successful if there is an aquifer on location which can facilitate sufficient flow extraction.

4.11 Case Study: Lewis Glucksman Gallery

The Lewis Glucksman Gallery, as shown in figure 31 below, is a cultural and educational building located on the banks of the river Lee within the main University College Cork campus.

Figure 31: Shows the Lewis Glucksman Gallery.

It is a seven story, 2350 m^2 art gallery with art exhibition space and storage, multifunction rooms, lecture facilities and a café. It was architecturally designed with the lower floors cladded in limestone and the upper-floor facades constructed from wood.

4.11.1 Technical Analysis

Building design

The landmark building was designed to be environmentally sensitive. The basic principles of sustainability were incorporated; including minimum artificial lighting, low U-value building fabric and an energy efficient heating and cooling system. The structural design of the building takes advantage of maximum possible passive solar heating. Due to its function, the gallery has a need for temperature and humidity control. This requires simultaneous heating and cooling, which proves very expensive with conventional plant consisting of a boiler and chiller. The sustainable energy systems present in the Glucksman Gallery were incorporated at the design stage, allowing for full integration. The new building has no visible external plant and no external fans and subsequently, no external noise, which is critical been an educational building.

Installed System

The heating and cooling loads were determined at 190 kW and 130 kW respectively, with the final design specifying a heat pump with 200 kW heating and 170 kW cooling capacity. This is a ground source heat pump (GSHP) with combined heating and cooling plant (CHCP). Meeting such large demand is only made possible by the location of the site in the Lee Buried Valley, a hydraulically conductive aquifer which follows the path of the lower River Lee. Water is pumped from two 12 m deep boreholes to two heat pumps located in the basement of the gallery which generate chilled water at 6 °C and hot water at 45 °C. The geothermal system primarily serves the exhibition and storage spaces where specific temperature and humidity control is required through under-floor heating and fan supplied air heating. Two 109 kW natural gas boilers provide heating for the remainder of the building, taking any excess capacity from the geothermal system.

Heat Pumps and Mechanical Plantroom

The system has two heat pumps generating chilled water at 6°C and low grade hot water at 45°C, one unit of capacity 2 x 37.5 kW while the other has 2 x 60 kW. The system operates in the same basic way in which all heat pumps operate, that is by extracting heat from the aquifer when in heating mode and delivering heat from the building to the aquifer when in cooling mode. The condenser is connected to the hot buffer tank and the evaporator is connected to the cold buffer tank. The building temperature is regulated using water from two 2,000L buffer tanks. The temperature of the water in these tanks is maintained within certain limits while the temperature in the cold tank is not allowed drop below 6°C to prevent the water freezing. All hot water pipes are lagged with soft insulation; cold water pipes are lagged with rigid insulation to stop condensation forming on them.

There are two heat exchangers in the system. The smaller of the two is located at the hot buffer tank and is used to dump heat into the aquifer. The larger is located at the cold buffer tank for dumping heat to or extracting heat from the aquifer. It is larger as the temperature difference of the cold buffer tank and the aquifer water is less than the temperature difference between the hot buffer tank water and aquifer thus requiring a larger surface area.

After heat has been extracted from the incoming aquifer, the water is stored in a holding tank for use as service water in the building. This is a process known as gray-water harvesting and can have significant savings on water charges for commercial buildings. It is pumped back into the aquifer when the level becomes too high. Aquifer water does not mix with heating system water.

Heat Source

The heating and cooling loads were determined at 190 kW and 130 kW respectively, with the final design specifying a heat pump with 200 kW heating and 170 kW cooling capacity. Meeting such large demand is only made possible by the location of the site in the Lee Buried Valley, a hydraulically conductive aquifer which follows the path of the lower River Lee. It is 60 km long x 0.5 km wide and up to 140 m deep.

4.12 System Appraisal

Environmental Analysis

The installed system has resulted in a 256 tonnes of Co2 savings, 75% energy reduction and cost savings of €11,500 per year compared with a conventional plant.

Economic Analysis

The capital cost of the project was €180,000 for which €73,500 was obtained in the form of a grant from SEAI under the "Public Sector Model Solutions Investment Support Scheme". The economic analysis is based on energy usage information available from the SEAI; this is shown in table 22 below.

Conventional System			
Predicted Gas Usage	1,680 MWh @	€18/MWh	€30,240
Predicted Electricity Usage	50 MWh @	€98/MWh	€4,900
Total Operational Costs			€35,140
Heat Pump System			
Predicted Gas Usage	190 MWh @	€18/MWh	€3,420
Predicted Electricity Usage	200 MWh @	€98/MWh	€19,600
Total Operational Costs			€23,020

Annual Operational Savings	€12,120
Simple Payback Period (neglecting SEI Grant)	15 years
Simple Payback Period	9 years

Table 22: Shows an Economic Analysis of the Lewis Glucksman Gallery. Source: *[SEAI]*

4.12.1 Conclusion

Financially, the installation of the heat pump was a successful decision as can be seen from the economic analysis in Table 22 above. Savings of €12,120 annually or 35% have been achieved, leading to a payback period of 9 years when the SEAI grant is taken into account, which is significantly shorter than the design lifetime of the project. With fossil fuels prices likely to rise significantly in the future, the financial savings of this system will increase. The environmental savings are also a massive positive too. In order to achieve a higher efficiency in the system, one large evaporator could be used instead of the separate evaporators at present. This leads to significant electricity savings when the system is operating at part-load because of the larger surface area provided.

4.13 Application to Ireland

Although applicable to all buildings with sufficient land available for heat collection, installation cost has proved prohibitive in the residential sector. Even with the "Greener Homes" scheme explained in chapter 1 of €2,500 for a horizontal ground source or water source heat pump they are still significantly more expensive than the conventional alternatives shown below in Table 23. Due to reduced operating costs, these heating systems have an average payback period in the region of 10 years which is quite long. Despite this, heat pumps already play a significant role in the energy systems of some countries, with annual increases of 10% in about 30 countries over the past 10 years *[Lund, J., et al, 2004]*. However, uptake in Ireland and the UK has been modest. A relatively mild climate, poor insulation levels of current houses and lack of suitable heat pumps available are the reasons.

Heating Systems	Initial Investment** € VAT Inc	Purchased Energy		Operating Costs*
		KWh/year	Litres of oil equivalent/year	
Electric storage	8,061	22,222	2,106	1,294
Oil boiler	9,637	30,769	2,917	1,663
Natural gas boiler	9,637	28,571	2,708	982
Ground source heat pump	16,122	6,667	632	555

Table 23: Shows a cost comparison of different heating systems available in Ireland.
Source: *[SEAI Renewable Energy Information Office, 2005]*

Heat pumps could also play a role in the non-domestic sectors. They are particularly suited for buildings that have a high demand for space heating and sanitary hot water production, extensive work-in times and a simultaneous need for cooling. In large buildings, several individual heat pumps can be placed in different zones and each can be sized to meet the needs of the space it conditions. When properly integrated, a heat pump system can recover excess heat in one zone and transfer it to areas of the building requiring heating. This is ideal for commercial and public buildings such as swimming pools and hospitals and leads to significant energy savings.

Chapter 5:

5.1 Conclusions and Recommendations

5.1.1 Discussion

As the need to decouple industrial development and carbon emissions increases, more emphasis is being placed on renewable technology. In recent years, this focus has seen a considerable rise in the penetration of renewable energy to the electricity and transport sectors, primarily through wind turbines and mandatory biofuel obligations. However, to achieve the overall renewable target of 16%, Ireland will have to make significant progress in the renewable thermal sector over the next eight years. A 12% renewable contribution to thermal energy is required and the recommendations below will put this further into perspective.

To date Ireland may have failed to meet the interim target of 5% by 2010 according to a source from the Department of Communications, Energy and Natural Resources although this is set to be confirmed when the government release a report in late 2011 that aims to focus solely on tackling the 12% renewable thermal target. The report is set to detail an action plan to be put in place by the government to ensure that we meet the target. The action plan will contain a new scheme currently in its development stage which is set to compete with the renewable heat incentive scheme been implemented in the UK. This will be aimed at large thermal energy users such as industry and is said to contribute significantly towards meeting the target.

To stimulate growth in the area, policy changes are required which would ensure the provision of renewable heat is economic. It is only when this is achieved, that major progress towards the renewable target will be realised. Converting to renewable technologies often incurs a high initial capital cost and the government needs to address this more. As of the 14/09/11, the government are currently in the process of phasing out grant schemes outlined in chapter 1 such as the "greener homes scheme".

The study of the technologies carried out in chapter 3 shows that any target is unlikely to be met through one energy source alone, but rather a combination of strategies and policies which primarily promote the use of biomass. Biomass can be used as a fuel for renewable electricity via combustion and the production of steam capable of driving a turbine to generate energy. However, its real importance to Ireland lies in the production of renewable thermal and transportation applications since these sectors cannot be satisfied by other mature renewable technologies such as wind, tidal and hydropower.

Renewable thermal energy can be generated by direct biomass combustion of solid biomass; mainly wood and energy crop related products as shown in chapter 4. To implement this strategy it would require a large scale retrofit of heating systems due to the fact that this technology is applied at the end-point of the heat distribution chain, i.e. the individual domestic / commercial / industrial premises which required the heat. Therefore, the adaption of such a policy on a wide scale would have a high associated cost and more financial incentives and policies aimed at helping thermal users would be required. Biomass can also be processed to and upgraded to natural gas, which would allow the continued use of conventional distribution and heating systems. This process is known as biomethane upgrading and requires adapting the parameters of biogas, which can be produced from either anaerobic digestion or gasification as shown in the case study in chapter 4, to satisfy those who avail of currently available natural gas. Alternative methods of producing renewable heat such as heat pumps and solar thermal are also considered as part of the broader picture but may only be adapted where the technology operates at its best available efficiency.

Throughout the options listed for Ireland in pursuit of the 12% target, case studies were examined in order to gain an insight to the technology and its successful operation. For the option of direct combustion in the rural location, a biomass boiler at Kelly's Hotel was assessed. The biomass boiler installation at Kelly's hotel was typical of the projects funded by the current renewable heat funding scheme, ReHEAT, where 30% of the initial cost is provided by grant payment. The biomass boiler consumes locally produced wood chips to provide for the hotels considerable heating demand as it contains a swimming pool. From the results it can be seen that the project proved to be a very successful installation. The system has already paid for itself and will continue to profit the hotel, safeguarding it from high cost fluctuations in the oil market. It can also be seen that by switching the thermal energy supply fuel from oil to woodchip, a saving of 344 tonne /annum has been achieved.

Direct combustion in the urban setting was analysed through the CHP project in Dublin. The results of the environmental and economic analysis clearly shows that a district heating scheme utilising waste heat from power generation (Poolbeg) will be competitive with traditional natural gas heating. This is highlighted by the fact that all three scenarios outlined gave an acceptable payback period. Construction of the district heating network will allow for the utilisation of a major renewable heat source, the Poolbeg Waste to Energy plant and would contribute immensely to reaching the 12% target.

Non-biomass technology is demonstrated through the installation of the heat pump at the Lewis Glucksman gallery. This project has also proved successful, providing a significant proportion of the building energy consumption. The Glucksman gallery heat pump has a payback period of just 9 years, saving over €12,000 and the production of 237 tonnes of Co2 annually.

Anaerobic digestion is one of the technologies capable of producing biogas that can be further processed into biomethane. It could be applied through large scale plants located near the natural gas pipeline as shown in chapter 3. A small scale system at the McDonnell farm site in county Limerick was assessed in chapter 4. The electricity is sold to the national grid under the REFIT scheme. The plant receives 15 cent/kWh of electricity being exported, making the system economically and environmentally viable as the digestate from the process is returned to the land as a high value fertiliser.

5.2 To Reach the Target

The study of the technologies carried out in chapter 3 shows that any target is unlikely to be met through one energy source alone. Therefore to reach the target the potential renewable contribution from each fuel source and technology was estimated, taking into consideration an additional 591 ktoe is required by 2020 to reach the target. The results are put into perspective below.

- For direct biomass combustion, wood is the primary fuel. The potential wood available for combustion is 799 ktoe/annum; 224.5 ktoe from forestry and wood waste and 554.5 ktoe through the utilisation of excess arable land for miscanthus production.

- District heating schemes could provide up to 53.4 ktoe/annum. This is through the realisation of CHP to district heating schemes (26.4 ktoe) and the Dublin district heating scheme (18.7 ktoe).

- The potential for biomethane is 1,618 ktoe. This is achieved through the anaerobic digestion of available grass, agricultures slurries and slaughter wastes together with landfill diverted OFMSW. The potential energy production from this sector is large and it has the benefit of also acting as an effective organic waste management programme by contributing to waste management legislation. Although the high capital costs incurred in implementing Anaerobic digestion will inhibit this technologies full potential.

- The utilisation of both heat pumps and solar thermal is low in Ireland. Heat pumps have the potential to cater for a significant portion of thermal demand mainly in the residential sector, but the high initial costs remains a barrier. Targeted retrofitting of dwellings with solar thermal systems sufficient to satisfy their DHW requirements could generate 42.64 ktoe of renewable energy annually.

5.3 Recommendations

Following this thesis, key areas of development for the successful implementation of renewable thermal have been discussed. To reach the 2020 12% RES-H target, the author recommends the increased implementation of the various technologies studied. Taking the conclusions made in the previous sections into consideration, a number of recommendations have been drawn up to be made to overcome the general barriers to renewable thermal implementation, and these are as follows:

The education of the public with reference to the benefits of using biomass and other technologies to satisfy their thermal demand through technical seminars, workshops and ease of access to information on the area. Also the education of the public with reference to the benefits of energy efficiency to reduce our thermal energy demand should be implemented.

- Future planning conditions should promote high density housing and the use of district heating systems in urban areas where possible.
- Financial incentives in the way of a tax relief or subsidy for farmers This should encourage and help them to grow energy crops securing the problem of market supply and aid them in purchasing expensive specialised farm equipment.
- Re-think the decision to phase out the current Greener Homes and ReHeat grant programmes to promote homeowners and businesses to implement renewable thermal

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Declaration

I acknowledge that the work carried out in this report is that entirely of my own and that appropriate referencing methods were carried out where material was used from various sources.

Signed: Shane Longworth Date: 19/9/11

Shane Longworth 19/9/2011.