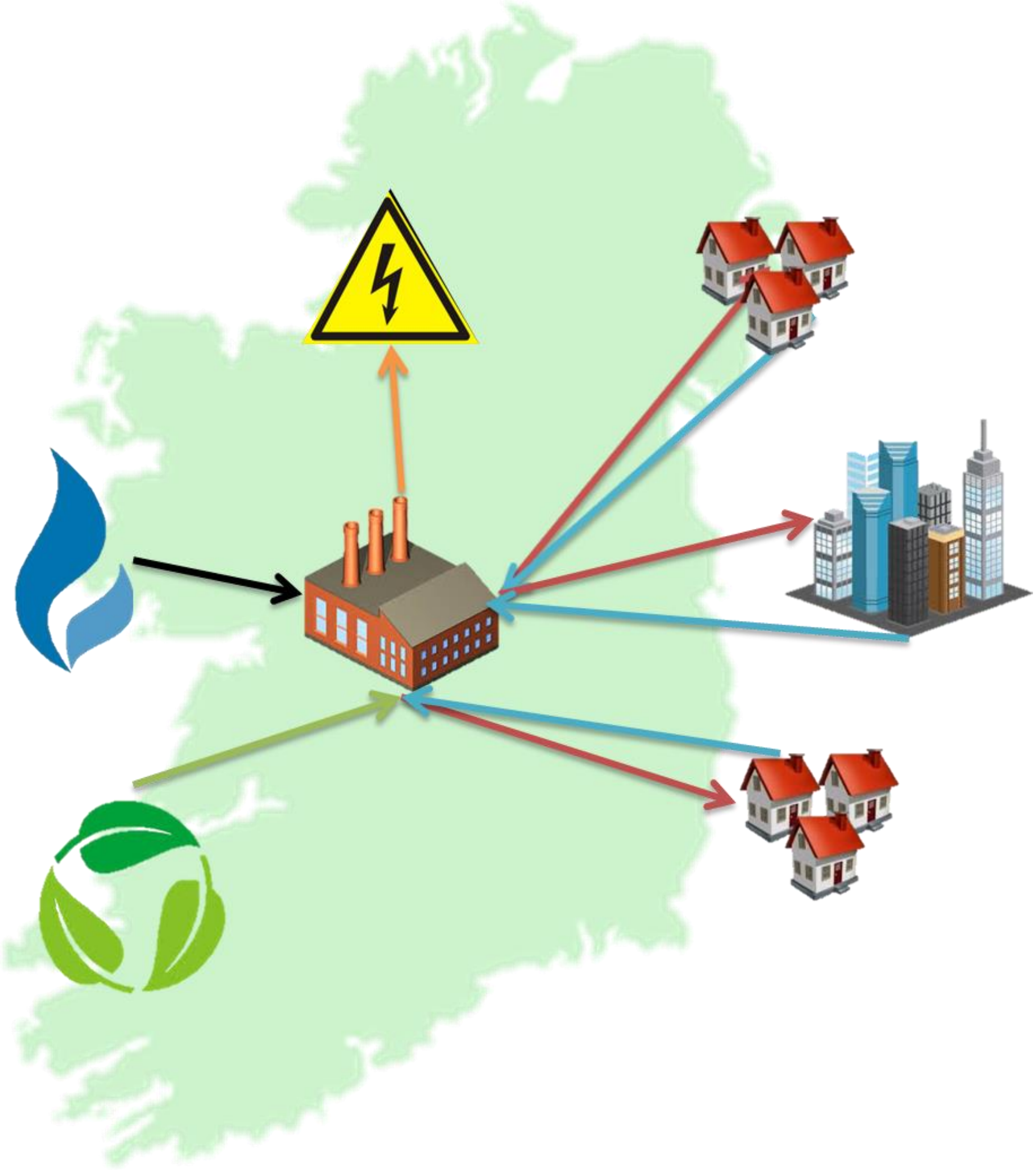
AALBORG UNIVERSITY MASTER THESIS

DEVELOPING DISTRICT HEATING IN IRELAND: WHY SHOULD IT BE DEVELOPED AND WHAT NEEDS TO CHANGE?



Donna Gartland

Sustainable Energy Planning and Management,
Department of Development and Planning

ABSTRACT

This study recognises the need to lower the levels of fossil fuel imports and increase energy efficiency in the heating sector in Ireland due to issues regarding security of supply and climate change. Ireland is heavily reliant on oil and gas to meet heat demands, and even though large scale District Heating (DH) has been proven to be an effective solution in other countries in Europe, particularly Scandinavia, it is currently not used in Ireland. The new EU Energy Efficiency Directive (2012/27/EU) puts more emphasis on energy efficiency in the heating sector, and under the Directive requirements, Ireland must carry out an assessment incorporating a cost-benefit analysis of the potential for DH in Ireland. If there is an excess of benefits over costs, adequate measures are required to be put in place to develop DH infrastructure and regional heat markets. With this in mind, this research paper conducts an in-depth hourly techno-economic energy system analysis, and consequent cost-benefit analysis, of a case study of a proposed large scale DH system in Dublin, Ireland. This kind of analysis of a DH system within a real life context is the first of its kind to be carried out in Ireland, to the knowledge of this author. The generality of the findings are deemed to be applicable to other areas in Ireland of similar or higher heat density and with similar heat demand profiles. The results show that DH is technically and economically feasible under current market conditions, and there are greater benefits than costs from a societal viewpoint. With this result, the study goes on to analyse the opportunities and barriers surrounding large scale implementation of DH in Ireland, and suggests policies and regulations which would allow the development of DH and regional heat markets in Ireland. The key findings show there is a need for coordinated, strategic, regional level sustainable energy planning in order to enact long term institutional changes surrounding DH. The results also show the need for short term financial supports designed specifically for sustainable and efficient heat production to influence market based investments.

This research paper was written as part of the Sustainable Energy Planning and Management Master Degree programme at Aalborg University, Denmark, and prepared in the period February to June 2014.

ACKNOWLEDGEMENTS

Firstly I would like to thank the Department of Development and Planning at Aalborg University for opening its doors to so many international students and allowing me to take part in this Master Degree course, which has been a truly valuable experience for me. Special thanks go to my thesis supervisor, David Connolly, for all his input, encouragement and support throughout the thesis writing process.

A great many thanks go to Codema, and in particular the director, Gerry Wardell, who supported me throughout my internship and Master thesis, and gave me invaluable experience and confidence in my work.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

ACRONYMS

EU – European Union

US – United States

UK – United Kingdom

GHG – Green House Gases

CO_2 – Carbon Dioxide

RES – Renewable Energy Source

EE – Energy Efficiency

FF – Fossil Fuel

MS – Member States

NREAP – National Renewable Energy Action Plan

NEEAP – National Energy Efficiency Action Plan

SEAI – Sustainable Energy Authority of Ireland

TSO – Transmission System Operator

DSO – Distribution System Operator

CER – Commission for Energy Regulation (Ireland)

FIT – Feed In Tariff

SMP – System Marginal Price

EPC – Energy Performance Contracting

PAYS – Pay As You Save

Ktoe – Kilo-tonne oil equivalent

CHP – Combined Heat and Power

HECHP – High Efficiency Combined Heat and Power

DHC – District Heating and Cooling

DH – District Heating

DEA – Danish Energy Agency

ESCO – Energy Service Company

DCENR – Department of Communications, Energy & Natural Resources (Ireland)

DPER - Department of Public Expenditure and Reform

DCC – Dublin City Council (Ireland)

SDCC – South Dublin County Council (Ireland)

Codema – City of Dublin Energy Management Agency

SEAP – Sustainable Energy Action Plan

LARES – Local Authority Renewable Energy Strategy

INTRODUCTION

THE NEED FOR CHANGE

Climate change is now widely recognised as an issue of increasing significance to the global environment. The topic has been brought to the forefront of media attention recently with increasingly unpredictable, violent weather systems, which have seen many countries experience the most devastating weather since meteorological records began. According to a new publication co-authored by the UK's Royal Society and the US National Academy of Sciences, *Climate Change: Evidence & Causes*, the speed of global warming is 10 times faster now than it was at the end of the last ice age, with the last 30 years being the warmest in 800 years (The Royal Society & The US National Academy of Sciences, 2014). The scientists involved have also come to the conclusion that the latest changes in our climate are "almost certainly due to emissions of greenhouse gases caused by human activities" (The Royal Society & The US National Academy of Sciences, 2014, p. B9). This report is just one of many evidence and research based papers from all around the world which have made it impossible to deny that GHGs are responsible for climate change, and it is imperative to act now in order to curtail the irreversible damage caused by these emissions.

Since the Kyoto protocol in 1997, curbing the effects of greenhouse gases (GHGs) on our eco-system has been firmly placed on the political agenda. Reducing energy consumption and finding alternative, non-polluting, and renewable sources for energy production are the target areas for policies so that countries may meet their international obligations to reduce their CO_2 contributions. There are also many knock-on benefits to reducing CO_2 levels and implementing more renewable energy, including reduced health effects, decreased fossil fuel dependence, higher security of supply, lower energy costs, increased economic competitiveness and a sustainable economy. In Europe, the European Union (EU) have set ambitious targets of 20% reduction of EU GHGs from 1990 levels, 20% of energy consumption to come from Renewable Energy Sources (RES), and 20% improvement in Energy Efficiency (EE), by 2020, also known as the "20-20-20" targets. The EU are ensuring Member States (MS) meet these targets through directives which specify targets for RES and GHGs and binding measures for EE for each MS. While work is still ongoing to reach these targets by 2020, the EU have just announced (January 2014) new targets for 2030, which will aim for a 40% reduction of EU domestic GHG's from 1990 levels (European Commission, 2014).

TACKLING CLIMATE CHANGE IN IRELAND

Ireland has adopted and transposed these EU directives into Irish legislation, which are outlined in two main relating documents; the National Renewable Energy Action Plan (NREAP), and the National Energy Efficiency Action Plan (NEEAP). There is also a new Climate Change Bill and Low Carbon Roadmap in the process of being finalised. Ireland has a target of 16% of the country's gross final consumption to be supplied by RES and a 20% reduction of non-ETS GHG's from 2005 levels by 2020 (EPA, 2011). Although there are no set targets for EE, there are binding obligations set out in the EU Energy Efficiency Directive 2012/27/EU. Ireland has committed to the 20% energy savings along with a 33% target for the public sector. The strategies to meet these targets are analysed under the three energy consuming sectors; electricity, transport and thermal. In 2012, the split of total primary energy use under these headings was 35%, 32% and 34% respectively (SEAI, 2013 (a)). The split in energy related CO_2 emissions for these applications is 32.2% from electricity, 32.8% from transport, and the highest share of 34.9% from thermal (SEAI, 2013 (a)). Although the split in energy use and CO_2 emissions is fairly even across all three applications, there is an imbalance in the related policies and initiatives in the aforementioned action plans. Ireland's NREAP focuses on the implementation of RES, mainly wind, into the national electricity grid, with an ambitious target of 40% of electricity from RES by 2020 (DCENR, 2010). There are many support measures in place for large grid connected RES, such as Feed in Tariffs (FIT) and priority dispatch. The transport sector has a target of 10% of electric vehicles (which is the lowest target for RES in transport allowable by the EU) and the heating sector has an unambitious target of 12% from RES, planned to be primarily provided by biomass (DCENR, 2010). The NEEAP is focused on reducing public sector energy use, and creating new ways to fund energy retrofits, for example through Energy Performance Contracts (EPC) and Pay As You Save (PAYS) schemes (DCENR, 2012), as most previous schemes were cancelled due to public funding budgetary constraints. Overall, the targets and related incentives for the electricity sector far outweigh those for the transport and heat sectors, even though the share of primary energy use and emissions by each application is fairly even.

This may be influenced by the fact it is easier to reduce emissions which fall under the EU Emissions Trading Scheme (ETS), which are mainly those from power plants, than those outside the ETS, which are mainly in agriculture, road transport and heat sectors. It is less complicated to use an alternate power source on the grid, with vast resources of wind available, than to change the heating systems in each individual building or change the fuel used in each individual car. Decreasing the emissions in the heating sector is a real challenge; if there were already an established heat market in Ireland, like that of the electricity market, it would be a much simpler process to integrate RES, than to retrofit all existing individual heating systems.

HEAT MARKET IN IRELAND

Latest figures show the thermal demand in Ireland accounted for 34% (4,468 ktoe) of total primary energy demand in 2012, and only 5.2% of total thermal energy is produced from RES. In the same year, thermal energy from renewables accounted for 2.1% of gross final consumption, compared to a 4.2% contribution of renewable energy from electricity generated (SEAI, 2013 (a)), which again shows the greater influence of RE policies aimed at the electricity sector. The vast majority of RES in the heat sector is from biomass fuel and in the electricity sector is from wind power. The residential sector is second only to the transport sector in share of total final energy consumption (SEAI, 2013 (b)), and with approximately 83% of total final fuel use in residential sector used for space and water heating, and only 8.5% of this provided electrically, this means that even if the electricity supply was 100% based on RES, it will only affect a small percentage of the overall energy used in this sector. Below is a chart by the Sustainable Energy Authority of Ireland (SEAI) showing best estimates of thermal energy end-use in Ireland, and as can be seen, thermal demand far outweighs non-thermal energy demand.

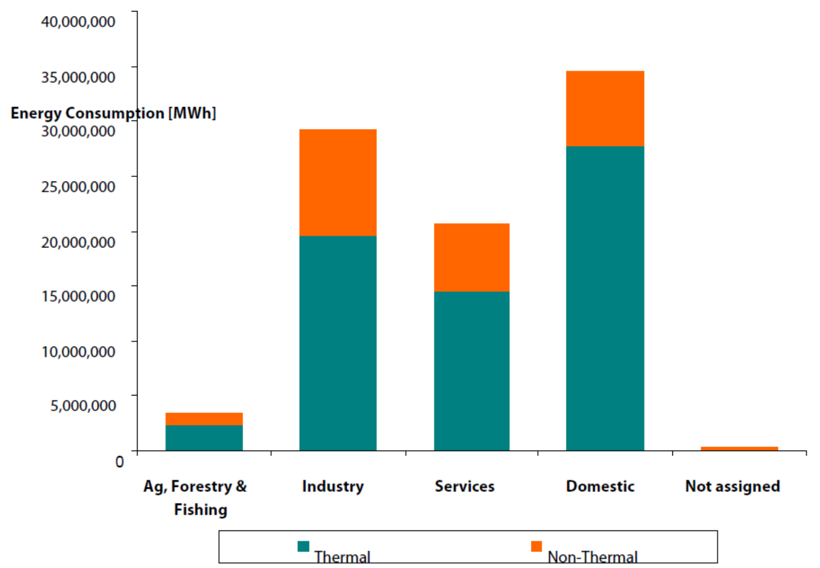


FIGURE 1 ENERGY CONSUMPTION END-USE SPLIT IN EACH SECTOR (SEI, 2008)

Residential heat is majority supplied by individual household gas or oil boilers, with smaller shares of solid fuel burning, and electric heating used primarily in apartment buildings in the form of storage heaters. CHP is recognised as a means of improving energy efficiency in both electrical and heat production and can result in up to 50% reductions in CO2 emissions, and with this in mind Ireland have set a target of 800 MWe from CHP by 2020 (DCENR, 2012). Latest figures for CHP in Ireland show that there are 325 units, of which 243 are operational. The operational installed capacity is 306MWe, which is nearly 500MW off the 2020 target (SEAI, 2013 (a)), and given the increase between 2011 and 2012 was just 4MW, there is a need for much greater incentives for CHP if Ireland is to achieve anything near the set target. Of the 330MWe total installed capacity, less than 4% is from renewable sources, with only 5.5MWe fuelled by biomass and 5.8MWe from biogas (SEAI, 2013 (a)). According to the SEAI close to 100% of all heat produced in CHP plant was useful heat output, and based on 2010 figures, the vast majority of CHP operational capacity is used in industrial applications (SEAI, 2012 (Update)). There are currently no large scale District Heating (DH) systems in Ireland, with any DH that has been developed outside of industry being limited to single apartment complexes, hotels etc., and only a handful of sites connecting more than one building. The existing DH systems are fuelled by CHP or boiler systems, there are currently no DH systems fed by waste heat, industrial surplus heat, geothermal, solar thermal or waste to energy plants. There are many barriers to DH outlined in different DH feasibility studies in Ireland, with the Department of Energy outlining some of the reasons for lack of DH including population dispersal, lack of energy intensive industry, temperate climate, the economic recession, and low levels of construction and forestry. Most of these barriers are outcomes of the report *'The assessment of the Barriers and Opportunities Facing the Deployment of District Heating in Ireland'* carried out by the SEAI in 2002 in order to provide strategic information to the Irish government; low levels of construction and the recession are more recent issues which have been added to the list of barriers. The reasons these are perceived as barriers are analysed further later in this report. Many past studies in the area of DH in Ireland outline characteristics which make the 'ideal' situation for DH development, and these include new developments under construction, areas of mixed building use, a 'DH Champion' to push the project forward, local authority involvement, areas where there is waste heat energy from industry, and areas of high building density.

The high penetration of individual gas and oil boilers to meet heating requirements and the subsequent large established gas grid and oil delivery services means that there is a "lock-in" to technologies which feed into these systems. The current policies and public funding available to upgrade old inefficient individual boilers with new efficient gas and oil fuelled boilers means that it will not make economic sense to convert these to a DH fed network until close to the end of their lifetime. These end-of-pipe solutions are easier, cheaper, and suit the already established energy system, and so new innovative energy solutions fall victim to path dependency.

The current policies surrounding the heating sector are aimed toward renewable sources and high efficiency CHP, and reducing heat demand in buildings. The renewable energy directive gives priority dispatch to electricity generated from renewable sources, such as biomass CHP, and the energy efficiency directive gives guarantees of transmission and priority access and dispatch to HECHP (DCENR, 2012). To meet CHP targets, the supports in place are Feed-In Tariffs (FIT) for biomass fuelled CHP, Accelerated Capital Allowance (ACA) (100% tax write off) for qualifying EE equipment (SEAI, n.d.), and a carbon tax rebate scheme for HECHP (Revenue Commissioners, 2013). The current FIT for large biomass (above 1.5 MW) CHP in 2014 is €125.84/MWh (DCENR, 2014), which is around double the current average SMP. Carbon taxes were introduced in 2010 and apply to heating oil, gas, coal, peat and other solid fuels in non-Emission Trading Scheme (ETS) sectors. The energy performance of buildings directive ensures new or renovated buildings meet minimum energy performance standards.

The new '*Green Paper on Energy Policy in Ireland*', released during the completion of this study in May 2014, is now open for consultation (DCENR, 2014). The paper sets out 6 priority areas which frame the discussion, with priority 4 concerned with 'Ensuring a Balanced and Secure Energy Mix', and outlines plans for the future of the heating sector. While it recognises the need for lowering reliance on oil and increasing fuel diversity, the fuels outlined to be optimised in the heating sector are electricity and gas to "*replace more carbon intensive fuels*" (DCENR, 2014, p. 50), with the main focus of integrating renewables in the form of biogas injection into the gas grid. The paper cites the REFIT and new building requirements will increase the use of renewably fuelled CHP.

THE FUTURE: INDIVIDUAL ELECTRIC VS DISTRICT CHP HEATING SYSTEMS

There is discussion in Ireland at the moment as to what a better solution to heating requirements is; individual electrical heating units in the form of 'smart electric thermal storage', or centralised district heating units. This discussion is fuelled by the fact Ireland has a high resource of renewable electricity in wind power, the potential for demand side management, and improvements in efficiency of electrical heating equipment. The latter point is being driven by Ireland's biggest electrical heating manufacturers, Glen Dimplex, who has invested heavily in their new 'Quantum' smart grid enabled electricity storage system (Doyle, 2013). Ireland's supply of renewable electricity is from a highly fluctuating resource, meaning that a flexible demand, flexible production, or both, is required for balancing. Flexible demand could be achieved through integrating a smart grid system for electric appliances, including heating systems, which would power on/off to coincide with times of high/low wind power, but this kind of system has limitations. These limitations include the large investment needed for implementing smart meters in all individual premises, the speed at which these loads can be switched, limited times when users need heat, high coinciding demands for heat meaning increased peak back-up required, and user behaviour cannot be effectively controlled. The most sustainable and efficient choice for heating solutions should be sought first, and then other beneficial attributes can be appraised. DH using CHP and heat pumps can both provide sustainability and efficiency for heat production, and can also contribute to grid stability, with the ability to use electricity in times when the spot price is low, and produce when the price is high.

Using expensive centralised fossil fuel power plants is the current solution to covering times of peak demand, and the roll out of a nationwide smart grid system has been put on hold. In Germany, the ambitious move to increase renewables and decrease nuclear energy has seen the share of renewable electricity rise to 25%, but also seen the amount of coal and lignite used in electricity production increase, and with plans to open 17 new coal and lignite power plants by 2020, the reliance on fossil fuels with high emissions is set to continue past 2050 (Michel, 2014). Ireland could be in the same position unless there is more focus on alternative sources and means of grid regulation, and decentralised bio-fuelled CHP units can be part of the solution. There have been studies of the Danish energy system which show the benefits of using decentralised CHP units, coupled with thermal storage and heat pumps, in order to meet both heat demand and the fluctuations in wind supply, rather than simply relying on importing/exporting to neighbouring countries (Lund & Clark, 2000). This is even more important from an Irish perspective, as Ireland does not have the same level of interconnection with other countries; Denmark for example is connected to Norway, a country which has an abundance of hydro power to help balance fluctuations in wind power.

Irelands interconnections may in fact hinder the use of electricity for heat; a recent report by the Economic and Social Research Institute (ESRI) has shown that the UK tax on fossil fuel will not only cause a rise in the price of electricity in the UK, but in Ireland also, due to the interconnections between Ireland and Northern Ireland[1] and Wales (Curtis, et al., 2014). The energy providers across the border in the North will be forced to look for exported electricity from Ireland, and the extra competition will cause more pressure on generation stations in Ireland and raise the SMP. Electricity will become even less competitive than using other fuel sources for heat such as biofuels. If all heat demand is supplied by decentralised production units, it is less expensive and less complicated to change to other fuel sources when needed, rather than refitting each individual system. It has been shown in studies by Connolly *et al* that district heating is a more feasible socio-economic alternative to individual heating solutions in Europe in areas where there is sufficient heat density (which is approximately 30% of the heat demand in Ireland) and areas where there are waste heat sources from industry and energy production, and the study identifies heat pumps as the most feasible individual heating solution for other areas (Connolly, et al., 2014).

[1] Northern Ireland is part of the UK

Denmark is already in the process of converting decentralised CHP units to renewable fuels in order to decrease the amount of FF use, therefore contributing to RE quota's for the electricity sector, and also, when combined with DH, reduces the CO_2 and FF use in the heating sector. If Ireland electrifies the heating demand using electric heaters, even with smart grid enabled flexible demand, the grid will rely on an even larger number of FF based centralised plants to meet times of shortfall. The large scale deployment of balancing CHP units powered by biofuels, which produce electricity when needed and store heat, should be strongly considered for the overall benefit of an Irish electrical grid with high penetrations of RES, a heating sector based wholly on fossil fuels, and for the security of supply and emission reductions Ireland needs.

DISTRICT HEATING

Both the EU directives on RES and EE include articles relating to Combined Heat and Power (CHP) and District Heating and Cooling (DHC). Article 16 of the Renewable Energy Directive 2009/28/EC and Article 14 of the Energy Efficiency Directive 2012/27/EU focus on the promotion of district heating and cooling from renewable energy sources such as biomass, solar and geothermal, and the use of High Efficiency Combined Heat and Power (HECHP). The NREAP states Ireland's "policy objective is to work to overcome existing challenges and deliver district heating commensurate with the characteristics of the Irish Market" (DCENR, 2010, p. 97). The plan also states that supporting actions are required for DH such as a regulatory framework for the heat market, but as yet, there are still no regulations, policies or initiatives directly relating to either DH or a heat market in Ireland.

Article 14 of the EU EE directive, for the promotion of efficiency in heating and cooling, focuses on the use of cogeneration and DHC. It requires that "Ireland must carry out a comprehensive assessment incorporating a cost benefit analysis of the national potential for the application of HECHP and efficient district heating and cooling" (DCENR, 2012, p. 44)by December 2015. The study is also to include a country-wide description of the heating and cooling demand. The directive specifies Ireland must identify strategies to develop DH to allow the increased use of HECHP, waste heat and RES. If the outcome of the assessment proves to be positive, then Ireland must adopt measures for the development of DHC from HECHP, RES and waste heat, and associated infrastructure. From June 2014, Ireland must enact requirements for a cost-benefit analysis of the possible use of HECHP, waste heat use or DH connection when any new or refurbished thermal electricity generator, industrial development, or DHC network is planned. What is also interesting, particularly from the point of view of municipalities, is the requirement for Ireland to adopt policies to encourage the use of efficient heating and development of heat markets specifically on a local and regional level.

These new requirements mean that there has to be a full detailed analysis of the effect DH would have on energy use and its related costs. It has been suggested by studies from Denmark, such as that of Connolly *et al.*, that the investments into DH need to be analysed from a societal perspective, as the structure of DH networks do not lend well to the priorities of a market economy, such as short term payback (Connolly, et al., 2014). It is therefore important to establish from what perspective the cost benefit analysis will be taken. If the DH analysis proves to be advantageous, Ireland has to implement ways to encourage its use, and so will create impetus in the heating market in Ireland. Implementing the infrastructure needed to develop HECHP and waste heat fed DH on a local and regional level will require major restructuring of the current planning and energy related policies, as currently there are;

- No policy or legislation directly relating to DH
- No mention of DH in the NEEAP
- No mention of DH in planning guidelines for the Greater Dublin Area (GDA)
- Very little uptake of HECHP
- Very little knowledge of implementing DH
- No regulation for local or regional heat markets

DHC is well established in other European countries, in particular in Sweden, Finland and Denmark, where historically DHC systems have been designed with efficiency as a priority. The capital of Denmark, Copenhagen, is the current European Green Capital 2014. Since the 1920's the Danes have been developing DH in order to protect the population and the economy from the rising prices of, and increased dependency on, fossil fuels. Copenhagen now has a vast DH network which provides 98% of the city's heat requirements, 30% of which is fuelled by biomass (City of Copenhagen & Ramboll, 2012). Both Ireland and Denmark have similar temperate climates on average, but Denmark has higher and lower peak temperatures in summer and winter respectively (DMI, 2013) (Met Eireann, n.d.). The city of Vaexjoe, Sweden, which has one of the lowest CO_2 per capita levels in Europe at 2.7t, has a large DH network which provides heat from biomass to 90% of its inhabitants (Naharnet News, 2014).

The city of London has an in-depth manual available for energy planners and local authorities to guide them in the process of developing and encouraging the use of DH in the city. The UK Government have just announced (April 2014) the launch of the Renewable Heat Incentive, which will pay homeowners a tariff, similar to the feed in tariff for renewable electrical power, for each kWh of heat produced by solar thermal, biomass boiler or heat pump. The hope of this scheme is to replace all fossil fuel based domestic systems with individual RES systems, but it seems counter intuitive to do so in high heat density areas where DH is also being encouraged. In comparison to Ireland, the UK have a much lower penetration of fluctuating RE in the grid and have nuclear power for balancing requirements, meaning deployment of decentralised CHPs does not provoke the same benefits of stability as it does in the Irish situation.

There are multi-faceted reasons why any innovative project will fail or succeed; timing, economics, policy change, cultural preferences, political preferences and more all play a part, and it is important to understand the heterogeneous nature of engineering (Law, 1987) when comparing the technological and social progress in Ireland to that in other countries. If Ireland is striving for self-sufficiency and security of supply, then a custom made energy solution for Ireland must be sought.

PROBLEM FORMULATION

As can be seen from the previous chapter, there is a need to reduce the amount of energy consumption and fossil fuels used in the heating sector in Ireland. It has been shown how the EU has identified DHC and HECHP as major contributors in reaching these goals. Ireland currently has no large scale DH systems and very little use of HECHP, especially from RES. This means that Ireland has to reform a large part of the national energy framework in order to accommodate and encourage energy efficient DH and CHP infrastructure in order to meet EU targets and obligations. In this process it is imperative to analyse the benefits of DH on both a national and on local and regional levels, in order to establish if and what policies and legislation need to be introduced or restructured at these levels, so that DH can take a foothold in the Irish energy market.

Ireland has just started to plan the comprehensive nationwide assessment of the potential benefits of DH and HECHP, but in order to develop specific policies at a local and regional level, studies also need to be carried out at this level. These studies also need to take into account the socio-economic benefits of DH in the long term, rather than just accounting for short term market based economics. The question is therefore;

Do socio-economic benefits outweigh costs when implementing large scale District Heating on a local level in Ireland? And if so, what policies need to be adopted in order to encourage the use of district heating systems, preferably fuelled by renewable sources and surplus heat, and development of heat markets at a local and regional level in Ireland, in order to meet the requirements of the EU Energy Efficiency Directive?

The first question is sought to be answered through a techno-economic study of a planned large scale district heating system in the Dublin region, which is a municipal planned retrofit project of existing large heat users. The study will be in cooperation with the City of Dublin Energy Management Agency, Codema. This project will be analysed through the energy planning software tool EnergyPRO which has been developed by energy planners in Denmark over the past 20 years. This software will take into account all technical and economic parameters of the potential DH system, and create an hourly model which will predict how the systems will operate in reality. The outputs of this study will contribute to the socio-economic cost-benefit analysis of local DH systems, with many technical, environmental and economic outputs. The analysis will also estimate other socio-economic parameters such as potential local employment and non-cost related benefits to customers.

To answer the second part of the research question, the energy model created will be used to see what changes would make the DH systems more/less economically attractive. Analyses of the current legislation and policy, recent feasibility studies, and discussion with relevant stakeholders will aim to find the current opportunities and barriers to DH and why it has not been developed on a bigger scale, and therefore identify potential changes. The legislation and policies surrounding the successful development of DH in other countries will also be used as inspiration for potential policies which could be implemented at a local and regional level in Ireland. Particular focus will be on Denmark, due to the high levels of DH already established there, and the author's particular knowledge of the system in this country.

DELIMITATIONS

This study's main concern is the heating sector requirements in Ireland, and does not analysis in any detail the electricity or transport sectors. This report examines the situation of DH in Ireland in detail, and does not investigate the situation in other countries to the same level. The report does not analyse in detail the effects of using CHP, heat pumps and thermal storage for the electrical grid, but assumes they have a positive impact based on literature review. The software, EnergyPRO, is used for energy system modelling as it is well established, allows hourly system analysis, has been developed with DH analysis in particular in mind, and guidance from expert users of the software is available through Aalborg University. No other software was considered or has been used in this study.

There are limitations to the techno-economic analysis of the case study, due to time limitations of the study period, lack of data available and due to lack of relevance for the particular case. These include;

- Does not include cooling loads
- Lifecycle emissions for the energy system and fuel are not taken into consideration.
- Does not allow heat to be rejected to atmosphere due to current legislation for HECHP
- Does not investigate possible industrial waste heat prospects or RES such as geothermal or solar thermal
- Does not analyse the system using a private wire network for local electricity supply due to current legislation

The reasons for these limitations are explained further in the case study chapter.

DEFINITIONS

- Socio-economic feasibility; whether a project is feasible from a societal viewpoint – "the best solution from an analysis of economical, environmental, political and social feasibility" (Hvelplund & Lund, 1998)
- Cost-benefit analysis; Evaluating potential costs and benefits that may be accrued during the lifetime of a business related action. In this report the cost-benefit analysis is taken from a societal viewpoint
- District heating; District Heating is a way of supplying heating through the delivery of hot water over a network of highly insulated pipelines, which is used in numerous individual buildings by way of individual heat exchangers. The source of the heat may be from one central energy centre, such as a large CHP, incinerator or boiler plant, or numerous heat sources which feed onto the network, such as industrial waste heat, solar thermal or geothermal sources. These systems often supply cooling needs as well as heating. A simplified diagram of a DH system is shown below.

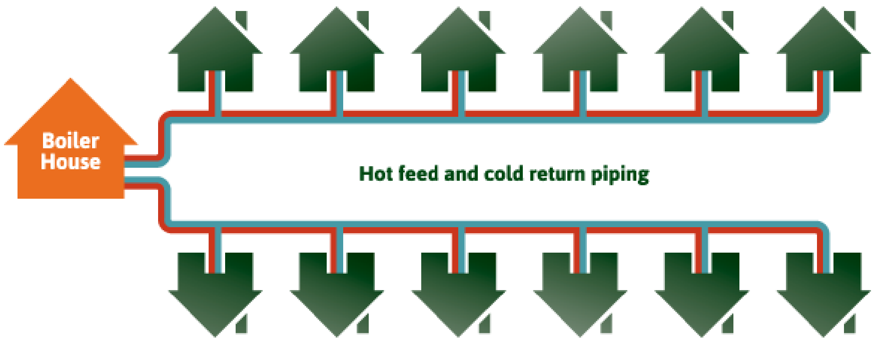


FIGURE 2: DIAGRAM OF DISTRICT HEATING NETWORK (SUSTAINABLE WOOD ENERGY, N.D.)

THEORY

This chapter discusses key concepts in order to create a theoretical framework for the research and to understand the reasons why the problem exists. The problem in question is the reliance on imported fossil fuels for individual heating system requirements and the current lack of support for, and implementation of, renewably fuelled and efficient district heating systems, as outlined in the previous chapter. The concepts discussed will cover economic, organisational, technological, cultural and sociological theory which surrounds the research topic. The dominant concepts of this research revolve around the issues new technological solutions face when trying to break into an already established market with a strong actor network that benefit from, and are in favour of, the current solution. The reasons why the barriers to new technological solutions are so strong are discussed, referring to the focus on economic growth, the influence of large organisations, perception in society, and path dependency. The concepts discussed are all inter-related, and serve to reinforce one another, which has led to the problem which currently exists.

EVALUATING ALTERNATIVES

In this case, the problem is not the technology itself, as the main energy production technology is already in use in the country at varying scales, and the networks or systems have been in use and are well established in many other countries in Europe with similar climates to Ireland. In this way, the problem is akin to the radical technological change described by Lund (Lund, 2010), but more a radical *system* change, the current system being made up of individual units meeting heat requirements. Lund speaks of Choice Awareness, which is described as the "collective perception of having a *true* choice" which involves consciously judging the merits of relevant options and selecting one for action (Lund, 2010). The lack of 'choice awareness' leads to alternatives which require radical change not being considered, and therefore the most beneficial option may not be available to select. The problem in Ireland is the general perception in society is that there is no other options for heating their homes and businesses other than that which dominates currently, and due to the lack of control afforded to local councils in terms of energy supply and the lack of cooperatives involved in the energy sector, society largely relies on the government and, to a greater extent, the private sector, to inform them of their choice.

THE PATH OF LEAST RESISTANCE

In society there are already existing solutions and technologies in existing systems which have grown and developed through time. These solutions and technologies then become embedded in that society, so that it is reliant on them in everyday life, and any change to that system has a large sociological impact. As an engineer or scientist it is important to recognise that there are barriers existing which are beyond the reasoning of scientific proof. The existing systems are enabled and protected by a Techno-Institutional Complex (TIC) which re-enforces their existence (Unruh, 2002). Unruh describes how actor-networks within a TIC are dependent on the current system (Unruh, 2002). New solutions which face into the challenge of total disruption of the current system face a longer uphill battle, even if it is a 'better' solution, whereas end of pipe or continuity solutions are easier implemented as it keeps more of the existing 'norms' in place.

ORGANISATIONAL POWER AND NEO-CLASSICAL ECONOMY

The organisations who are benefitting from the current system lobby the government to choose options from which they will continue to benefit, like end of pipe solutions such as electric heating, improved efficiency boiler units, etc., so there is no impetus to investigate a system which would involve a radical system change from those who have the most influence to enact change. The choices which are presented are often those which create the least disruption, least cost, and are based on short term business-economics, which suit governments who are reliant on re-election in the immediate future. The political capital of new organisations trying to establish a heat market will be comparatively low when compared to fossil fuel affiliated organisations (Hvelplund & Lund, 1998).

It is important to recognise the role of the market when trying to introduce radical change to the energy system. Hvelplund and Lund describe a neo-classical economy as based on the premise of a 'free' market; where all actors on the market are well informed, all suppliers are mutually independent, all buyers are mutually independent, there is no private regulation, all agents behave rationally, and public regulation measures are constructed neutrally (Hvelplund & Lund, 1998). This then supposes that the market is always operating optimally, when of course, in reality, all the above characteristics are not always met, and therefore the market is operating under a 'real' institutional economy.

In the Irish energy sector, the largest player in the electricity market, the state-owned ESB and its affiliates, own the transmission and distribution systems, over a third of the production units, and are one of the biggest players in the retail market, and therefore cannot be seen as being mutually independent, and have created a monopolistic energy scene. This organisation, along with others who benefit from it or are in a similar situation to it, can then create their own private regulation of the market, and argue that this 'real' market is operating as a 'free' market, and therefore retain their influence (Hvelplund & Lund, 1998). Information on energy in Ireland is often not released by referring to 'commercial interests', which again goes against the fundamental openness of a supposed 'free market'. Infrastructural investments by the public sector will support certain products on the market (Hvelplund & Lund, 1998), for example, the planned high voltage transmission grid extensions in Ireland will support large centralised power generation, whereas there is less focus on strengthening the distribution system to allow higher input from distributed energy sources. These types of publicly funded actions therefore interfere with the operation of the market. It is clear the energy market in Ireland operates under institutional economics, and yet when presenting the feasibility of new solutions they are judged assuming there is a free market in operation, and therefore assume that they can be judged on business economics as the market has supposedly created an optimum situation from a societal point of view. New solutions need to be deemed feasible according to long term socio-economic benefits in order for new public regulation to be introduced to allow technical innovation to break through the current barriers.

CHANGING PATHS

Through path dependency, society becomes integrated into a system, so much so that the existing solutions become preferential, expected and every-day life becomes dependent on them. This creates an inescapable situation, in which the probability of further steps down the path increases with each step down the path, known as Increased Return (IR) (Pierson, 2002). In the face of such enormous barriers, it often takes more drastic, unpredicted, changes to the norm to enable a radical system change. The traditional way in which large and drastic changes have been enacted is when an unpredicted event provokes the need for drastic change, for example, the 1970s oil crisis, and more recently, Fukishima. Even though it is known that the price of fossil fuels will continue to grow as stocks deplete, and that the emissions from the burning of such fossil fuels is causing irreversible changes to the planets ecosystem, these events are not seemingly not immediate and drastic enough to warrant drastic change to the way energy is produced and used in Ireland. It is therefore most likely that drastic change to the heating sector will only be enacted if (and when) there is a crisis affecting the current norm. A European gas crisis is not far from possibility in the wake of the current Ukraine crisis, as almost half of Russia's gas bound for European markets passes through Ukraine (Gloystein, 2014), and around 30% of European gas comes from the Russian market (Weymouth, 2014). The Irish government will likely wait for EU direction on energy policy before taking any decisions on a large scale shift away from gas use. Ireland has heavily relied on EU initiative for changes to energy policy, which may also contribute to the lack of policy focussed on the heating sector, as this has also been lacking in EU directives (Heat Coalition, 2014).

INFLUENCE OF THE SYSTEM OF GOVERNANCE

The establishment of a heat market is suited to a nationally envisioned, internal initiative, rather than an international effort, as there is no possibility to export heat to other countries, unlike fuel and electricity. Large established players in the latter sectors will obviously push for continuation and growth in their own markets on a European scale. Historical reliance on externally founded energy initiatives has led to Ireland having never had the chance to evolve plans which benefit the energy system as a separate entity to Europe, and therefore it is imperative Ireland not rely on external direction to establish an internal heat market.

There is also a lack of integrated energy planning at a regional level, as the electricity supply is dealt with at a national level, and there is no existing commercial supply of heat. The provision of heat is seen as an issue to be dealt with by individuals rather than the municipality and so no planning guidelines exist for DH. Local governments in Ireland do not traditionally include considerations for future energy supply scenarios within regional planning guidelines; most municipal planning departments do not have an energy expert or planner. National energy plans are rolled out on a national scale and it is not shown how these initiatives will impact each region, instead it is left to the private sector investors to choose areas in which to develop the sector under national guidelines. The current state of governance therefore benefits the already established private sector energy organisations.

INFLUENCE OF THE GROWTH ECONOMY

From an institutional context, it is important to recognise the dramatic change in status of the Irish economy in the last 6 years since the economic recession in 2008. There were more incentives and support in place for innovative sustainable energy solutions before this time. The current state of slow economic recovery has led to the unwillingness to involve public investment in innovative systems, even if they present long term socio-economic benefits. If Ireland does not focus on the long term benefits of a radical system change for the heating sector due to a lack of ability to fund such initiatives, then the gap between the development of the energy sector in Ireland and the rest of Europe will continue to grow, which is outlined by (Hvelplund & Lund, 1998); "*If countries with very scarce financial resources undertake a very defensive attitude towards participating in the needed technological innovation processes at the energy scene, they will stay behind in the technological development process, and continue to be dependant receivers and not developers of new technology*." The support for the Green party has dropped since they withdrew from government in 2011 due to pressures during the worst part of the recession, meaning the green agenda has taken a back seat in the political forum in recent years.

To try to enact change on the basis of socio-economic and environmental feasibility faces a large barrier in the form of the dominant global model of economic growth. Social structures and norms evolved inside a capitalist society create overwhelming obstacles when trying to promote projects which prioritise the benefitting of society as a whole, rather than economic advantage for few. In 2005, 80% of Irish citizens responding to a European survey ranked climate change as the third most serious problem faced globally, but since the economic crisis, these attitudes have changed, with a large increase in those prioritising economic growth over environmental protection, and this shift in attitude is more prevalent in Ireland than other EU countries (Kavanagh, et al., 2012).

All of the concepts discussed above have amalgamated to form the existing problem faced in this research paper. The following chapter outlines the ways this report seeks to find answers to the problem set out in the problem formulation.

METHODOLOGY

This chapter outlines the methods of analysis used in order to seek answers to the perceived problem outlined in the problem formulation. The main component is a case study research design, as mentioned in the problem formulation chapter, with the majority of the report connected, directly or indirectly, to the case study chosen for analysis. The case study involves both qualitative and quantitative aspects within a real life context.

RESEARCH DESIGN

Firstly a literature review ensures this research is as informed as possible and provides the background to the problem. From this the research question is defined to form the focus of the report, through the narrowing of the broader overlying complex phenomenon of climate change. After a review of current energy policy in Ireland and the level of fossil fuel use, it was found that the heating sector has not been regarded with the same importance as other sectors when implementing policy regulation and the established, efficient, technology of district heating is not in use at any notable scale in Ireland. All relevant literature in research, public policy, feasibility studies, directives and regulations relating to the heating sector and DH in Ireland has been examined. This review led to the identification of the current EU EE directive which details Ireland's obligation to carry out a cost benefit analysis of DH in Ireland, and enact initiatives to encourage its use if there are more benefits than costs identified. This led to the techno-economic and cost-benefit analysis found in this report, which are based on the results of a regional case study. The intention of this report is to show if there are higher benefits than costs, from a societal perspective, in a real life case study of one region in Ireland, with the generality of the findings applicable to other areas of similar or higher heat density in Ireland. This report will also seek to identify areas which are causing barriers to the implementation of DH in Ireland and ways in which these can be overcome through public policy and regulation.

CASE STUDY

The case study is based on one geographical area which was chosen based on the applicability to the research and due to the access to, and extent of, data available for an in-depth analysis. The techno-economic analysis of the proposed DH system in south Dublin is carried out from the perspective of the municipality, and takes the form of a market based business economic analysis. Access to information particular to this site has been provided by the City of Dublin Energy Management Agency. The results of the case study are seen to be applicable to any other geographical area with similar heat density and demand profile in Ireland. Technical, environmental and economic aspects of the case study will be provided through the use of the software tool EnergyPRO Version 4.2. The inputs for the modelling tool, asides from those attained directly from the municipality, are found through various methods, mainly literature review and online databases. This level of in-depth analysis of a real proposed DH system in Ireland has not been carried out previously, to the knowledge of this author. A description of the energy system analysis tool EnergyPRO follows in order that the processes inside the software are understood.

ENERGY MODELLING

EnergyPRO is an energy system modelling software package for combined techno-economic analysis and optimisation of cogeneration and trigeneration projects, and other systems with a complex mix of supply of electricity and thermal energy from many different production units (EMD International, 2013). EnergyPRO is typically used for analysis of district heating systems with many units, including renewables like biogas CHP, solar thermal, and geothermal, combining to meet the thermal demand, and incorporating use of thermal storage. The software allows very detailed modelling techniques, taking into account many aspects, such as; efficiency curves, ambient temperatures, degree days, demand profiles, operating strategies, tariff structures, varying fuel costs, interest on investments etc. The software optimises the use of all plant based on technical and financial inputs. As well as giving detailed outputs of the technical parameters, EnergyPRO produces detailed financial outputs such as monthly cash flows, balance sheets, and income statements, and produces reports on emissions.

The EnergyPRO module used in this study is the 'Accounts' calculation module, which calculates energy conversion, operational economics, investments, finances, income statements, balance sheets and tax, over a project period up to 40 years. The operation strategy used is the in-built strategy which minimises net heat production costs. This operation strategy calculates the net production costs for each production unit in all tariff periods, and forms a decision table. The software puts as much production on the least cost production unit/tariff period combination as possible, then fills the rest of the demand with the next least costly production unit/tariff combination, and so on until demand is met or there is no production capacity left (EMD International, 2013). These calculations are entirely based on the inputs relating to the revenues and operation expenditure.

The Net Present Value (NPV) is calculated based on a nominal discount rate input by the user, and brings all future monthly payments to present value. The discount rate here refers to that used to determine the present value of future cash flows, and is different to an interest rate on loans as it takes into account both time value and risk or uncertainty of future cash flows; the greater the perceived risk, the higher the discount rate. The Internal Rate of Return (IRR) is found by iteration using Newton's method, and expresses the nominal IRR, that is, the IRR is not expressed in the price level of a particular year. (EMD International, 2013).

All inputs used in the energy system model created in this report are explained clearly in the case study chapter. All other details of the EnergyPRO software can be found in the manual at http://www.emd.dk/energyPRO/Downloads/

LITERATURE REVIEW

A literature review is used to gain in-depth understanding of information which is important to the development of this study, such as current policies and legislations regarding the heating sector in Ireland, feasibility studies regarding DH in Ireland, and examples of DH from other countries. The results of this literature review are used throughout the report, but in particular contribute to the chapters of 'Introduction' and 'District Heating in Ireland and Dublin'. The author has made particular effort to try to gain as deep a knowledge as possible of topics relating to DH in Ireland, and there are over 100 sources cited in this report, with many more sources reviewed but not used.

STAKEHOLDER DISCUSSION

The author of this thesis report took part in and helped to organise a District Heating workshop, "*Developing Dublin's District Heating Potential*", as part of employment at Codema. The workshop was carried out as part of the *'Emerge: Sustainable Energy Community Dublin'* project from the SEAI. This workshop brought together a range of stakeholders interested in the DH sector to discuss the development of DH, and what barriers are holding back the implementation of DH on a large scale. The results of this workshop are used in this report in order to contribute to the discussion on what the perceived issues are and how to overcome these barriers. Stakeholders included representatives from the following agencies;

- RPS Consulting
- SEAI
- Dalkia
- Dublin City Architects Department
- Dublin City Council
- Tipperary Energy Agency
- Micro Electricity Generation Association
- BioXL
- Dublin Institute of Technology
- Tallaght Institute of Technology
- South Dublin County Council
- City of Dublin Energy Management Agency
- Fingal County Council
- Grangegorman Development Authority
- Tralee County Council

The workshop was held at the National Conference Centre on the 21st of May, 2014, and seen four presentations from; Assistant Professor David Connolly of Aalborg University, Donna Gartland (the author) of Codema, Tim Mc Swiney of Tralee County Council, and Paul Horan and James Rooney of Dublin Institute of Technology and Grangegorman Development Agency respectively. The presentation from David Connolly described the role of DH in the European energy system, and the author of this thesis then presented the current situation of DH in Ireland and policies which affect the implementation of DH in Ireland. The focus then turned to case studies of DH systems in Ireland; Tim Mc Swiney presented the 'Mitchels-Boherbee' small scale district system which has been successfully implemented in Tralee, and the last presentation described the project at Grangegorman in Dublin, where they are currently implementing a DH system in a new development. The presentations were followed by a discussion with all attendees invited to ask questions or raise points of importance. The video, notes and recordings taken during the workshop are used to inform this study, and the outcomes of this workshop are due to be published by Codema in 2014.

EMAIL CORRESPONDENCE

There were email correspondences with relevant actors in the area of DH throughout the research process, and copies can be found in Appendix B. The emails were used to ask questions regarding DH and provide accuracy in the research. Stakeholders and experts which were contacted include those staff in;

- Department of Development and Planning, Aalborg University
- Regional Planning Guidelines Office, Greater Dublin Area
- Ramboll, Danish Energy Consultancy
- South Dublin County Council
- SEAI

REPORT STRUCTURE

- **Introduction** – This chapter outlines the background to the problem formulation and is based on literature review
- **Problem Formulation** – This chapter presents the main research questions to be answered and outlines the delimitations and definitions important to the study.
- **Theory** – This chapter discusses concepts in order to create a theoretical framework for the research, and is informed by literature review.
- **Methodology** – Outlines the research design and methodologies used in order to answer the research question
- **District Heating in Ireland and Dublin** – This chapter introduces the reader to the current situation of DH in Ireland, and Dublin in particular. This chapter is based on literature review and stakeholder discussion.
- **Case Study: South Dublin County Council DH Project** – This chapter introduces the reader to the case study, and outlines the technical and financial inputs relevant for the case study analysis.
- **Results of Techno-Economic Analysis** – This chapter presents the results of the techno-economic analysis through the use of the EnergyPRO energy system analysis software, and includes a sensitivity analysis. The results of the socio-economic cost-benefit analysis are also presented.
- **Discussion –** This chapter outlines the opportunities and barriers for large scale implementation of DH in Ireland, and suggests policies and regulations based on all the preceding analysis in the report.
- **Conclusion** – This chapter summarises the findings of the report

DISTRICT HEATING IN IRELAND AND DUBLIN

So far in Ireland there have been no large scale district heating systems developed. There is also no specific guidance available for DH schemes (Ryan, 2014) and so there are numerous unknowns when planning such a system. There have been some large scale studies of the possibilities for DH in Ireland, and feasibility studies in some of Ireland's largest cities, namely Dublin and Cork. There was a national scale study of the opportunities and barriers to DH in Ireland carried out for the SEAI in 2002. This study has had quite an impact on the national position on DH, and is therefore analysed in detail in this chapter. Recurring themes from the review of literature associated with DH in Ireland are also discussed.

OPPORTUNITIES AND BARRIERS IN IRELAND: SEAI REPORT 2002

The SEAI report *'The assessment of the Barriers and Opportunities Facing the Deployment of District Heating in Ireland'* (referred to hereafter in this section as 'the SEAI study') was commissioned to provide strategic information to the Irish government, and it has been used as the basis for the Irish government's stance on the issue of DH in Ireland since its publication 12 years ago. The report concludes that many physical, behavioural, social and cultural factors together amount to "*numerous and seemingly insurmountable*" barriers preventing the development of DH in Ireland (SEAI & WS Atkins Consultants, 2002), and the report is further analysed in order to see how these conclusions were met.

The SEAI study states Ireland has a mild climate, does not have extreme cold winters and therefore does not have the same potential revenue from DH as other countries (SEAI & WS Atkins Consultants, 2002). If this is the case, and there are no large peak demands for heat in winter, there are also benefits to such climatic conditions; a CHP unit sized for base-load will cover more of the annual demand with higher full load hours, and much smaller peak load boilers are required, meaning lower investment costs. The mild climate could also mean less heat rejected during the summer, and therefore higher overall efficiencies. A feasibility study, '*District Heating for Dublin*', shows the annual heat demand calculated for a proposed large scale network, which used average Irish energy use figures and new energy related building regulations for new buildings, had a 20-30% higher heat load than a comparable Scandinavian DH scheme, taking climatic conditions into account (RPS/COWI, 2007), and cites consumer behaviour as one of the reasons the Irish heat demand calculated is so much higher.

Even without consumer behaviour considerations, much of the building stock in Dublin is old and has poor energy ratings which also contributes to large heat consumption; 57% of the city's residential sector was constructed pre 1970 and 70% use more than 225 kWh/m2/year, with the demand for space and water heating amounting to 83% of the energy demand (Gartland, 2014). Even if the energy efficiency targets of 20% reduction by 2020 are to be met in all housing, there will still be a significant heating demand in the established Dublin housing stock. The Danish Energy Savings Trust states that a low consumption residential building of 100m^2 uses 11.6MWh/year for heating in Denmark (City of Copenhagen, 2012), whereas in Dublin, the average household (which is much smaller than 100m^2) uses 18.2MWh/year for space and water heating (Gartland, 2014). More than half of all apartments in Ireland are heated electrically (SEAI, 2013 (b)), typically using storage heaters, and Dublin city has a large proportion of apartments at 35% of total housing stock (Gartland, 2014). The lack of control of the heat produced by storage heaters, and the high price of electricity, means these systems have gone out of favour in more recent years, and gas systems are more popular now for new builds (SEAI, 2013 (b)). The SEAI study shows the economics of a DH system are more competitive with existing heating systems based on electricity than those based on gas due to a higher price differential (SEAI & WS Atkins Consultants, 2002). An analysis carried out by Codema shows that an apartment block in Dublin, which was under construction at the time and planned to use electrical storage for heating, had a BER of D1 per apartment, which improved to a B2 rating if a CHP/DH system was to alternatively provide heat to the complex (RPS/COWI, 2007).

The SEAI study found the low price differential between gas and electricity to be a crucial factor in the feasibility of DH. The price differential referred to is related to the price paid for gas to fuel a CHP, and the cost of purchasing electricity from the grid. At the time of the SEAI study, the cost of gas meant the price at which the electricity could be sold from the CHP plant was not competitive with the price of electricity being purchased from the grid, meaning it was not advantageous to produce electricity for own use. In addition, the price paid by the ESB for surplus electricity (so-called 'spill' price) from CHP was very low. The SEAI study states the electricity price at the time was €0.1/kWh, this is in comparison to the present price of €0.23/kWh for a typical residential customer, and commercial customers can pay between €0.22 and €0.1/kWh depending on consumption, with the latter figure only applicable to very large consumers. Although the price for electricity has increased, so too has the price for gas. Electricity production in Ireland is largely provided by gas fired production units[2], thus the price of electricity is closely linked to the price of gas (CER, 2011) and the differential will not grow until this situation changes. The price differential between gas and electricity is a lot less relevant in CHP systems which are predominantly powered by renewables or waste heat, but these fuels are not focussed on in the SEAI study. The SEAI study also seems to concentrate on using electricity production for own use only, and with regulations forbidding the use of private wire networks, this restricts the SEAI analysis to small scale DH systems and ignores the benefits of distributed generation fed to the grid. There are biofuel options now which are cheaper per kWh than gas, have higher societal benefits than importing gas, and there are also guaranteed FITs for bio-fuelled CHP produced electricity fed to the grid.

The SEAI study found that the public perception of DH in Ireland is negative, mainly due to the poor performance of one system which was installed in the social housing complex in Ballymun in Dublin in the 1960s (WS Atkins Consultants, 2002). Much emphasis is put on this conclusion, even though, as the study states itself, "*no formal study has been made of the general public's awareness of DH*" (SEAI & WS Atkins Consultants, 2002, p. 23). The Ballymun complex has undergone major renovation over the last 20 years and the boiler house which provided the DH was decommissioned in 2010 (Dublin City Council, 2010). Due to the lack of DH in Ireland, and the low penetration of DH in the UK, the public awareness of what DH actually is is likely to be very low. It is likely that, at present, people outside of Dublin and the younger generation in Dublin would not be aware of the Ballymun DH project. There are many more benefits asides from monetary benefits for consumers of DH, and this, along with the current perceived unfamiliarity of DH, creates great opportunity for the positive promotion of DH.

A market assessment of the 'Dublin District Heating System' project, carried out by Codema, found there was an overall good response to the proposed DH system, and that organisations in the targeted area showed high interest in joining the planned DH network (Codema, 2012). The Codema report also found that the organisations were particularly interested in the sustainability of the project, with heat production planned to be provided by a large incineration plant. The commitment of these types of large organisations to a DH project would help to convince and give confidence to other close-by residential units contemplating joining the network. The implementation of many small, well planned, efficient DH projects has helped to promote a positive picture of DH, especially in Dublin where most of these projects are based; developments include Heuston South Quarter, The Point Village, Charlestown, Lansdowne Gate, Elm Park, and the Charlotte Quay Apartments (Ecoheat4EU, 2011).

There are numerous citations in the SEAI study regarding the lack of knowledge of DH systems in Ireland. This lack of experience creates an element of risk when planning and financing DH projects. Also, the returns from a DH system are not attractive to commercial investors, due to large initial investment costs of laying network pipes leading to longer payback periods (SEAI & WS Atkins Consultants, 2002). There is also risk associated with the uncertainty surrounding consumer connection, as consumers could withdraw from the service at any time and there are no guarantees that new customers will join the network. With these above reasons combined, there are many unknowns and risks involved in investing in a DH system.

[2] Over 50% of electricity production capacity in 2014 is gas fuelled.

The problem of customers leaving the system has been overcome in other Scandinavian countries through zoning of heating systems which obligate customers to join a network if it they are in a DH zone (SEAI & WS Atkins Consultants, 2002). The SEAI study states that this type of regulation would not work in Ireland as the citizens would not accept high levels of central planning, and therefore DH must be developed under 'free market conditions' (SEAI & WS Atkins Consultants, 2002). Irish households and businesses are already connected to centrally planned and controlled electricity, water and gas grids, so connecting to a centralised heating grid may not be as unacceptable as the SEAI study perceives. Connecting to a DH network that is paid by a top up card and meter would give more control over spending to the customer, along with numerous other benefits, which will be discussed later in this report. If there was greater community participation involved than is traditionally involved in other energy sector projects in Ireland, it could increase the acceptance of such a system. The SEAI study does not mention any probability than there could be cooperatives involved in DH projects in Ireland.

MUNICIPALITIES AS A DRIVER FOR DH

The involvement of local authorities in the development of DH is found to be crucial in many previous studies (WYG, 2009) (SEAI & WS Atkins Consultants, 2002) (RPS/COWI, 2007) (Hawkey, 2012). Ireland has recently gone through a process of privatisation of services which were traditionally owned and operated by the municipalities. The waste collection and more recently the water services have been handed over to other publicly and privately run organisations, so that now the municipalities do not provide any services directly to the homes of their constituents. The current system of governance does not afford the local governments any opportunity or encouragement to participate in the energy services sector, which is a barrier considering municipalities have been the drivers of district heating systems in other countries like Denmark, Sweden and even in the UK. In the UK, local governments have been assigned carbon reduction targets, which have pushed the importance of schemes like DH to the forefront of municipal agendas, and local authorities together with ESCOs have successfully developed 'joint cooperation' DH schemes (WYG, 2009).

In Germany there has been a lean toward re-municipalisation in recent years, with 44 new local public utilities being set up since 2007, and over one hundred concessions for distribution networks returned to public authorities (Reck, 2011), and this move is supported politically by green and socialist parties. The city of Hamburg recently voted in favour of re-municipalisation of the distribution networks for electricity, gas and district heating (Lang, 2013), as has many other cities in Germany. This regaining of control contributes to the participation of the community in the energy sector, with fewer barriers to connect to the infrastructure. In 2012, 47% of renewable energy was owned by citizens and cooperatives (German Energy Transition, 2013). It is always important to look to and learn from successful experiences in other countries, but it is also important to understand the institutional characteristics which surround a potential project in Ireland will never align with the past or current situation in other countries. It is therefore almost impossible to try to recreate the same outcomes using the same initiatives in the same way, meaning there needs to be a customised solution for the Irish institutional context.

CONNECTING TO THE GRID

Connecting to the electrical grid in Ireland has been cited in many reports as being a large barrier to the implementation of distributed renewable energy production, due to the long and complicated group processing approach (GPA) in place (Healy, 2013) (IWEA, 2014). The group processing approach is a method used by the TSO to connect 'batches' of generation plants to the grid, and these batches are called gates. At the moment the TSO are in the process of accepting generation offers in Gate 3, which opened in 2009. Gate 3 has quotas for 4000MW of wind generation and 1700MW of conventional generation (Eirgrid, 2013), with a higher allowance for wind due to the targets set out in the NREAP. A report from a large renewable developer in Ireland states that it has taken up to seven years for some projects to receive a grid connection under the current group processing approach (Fedorkiw, n.d.). At a 'Cooperative Power' conference recently held in Dublin, Erik Christiansen of Middelgrunden Offshore

Wind Cooperative, Denmark, described the process of connecting to the grid in Denmark; it took 2 days to hear back from the TSO to inform them they had permission to connect to the grid, with no costs (Society for Cooperative Studies in Ireland, 2014), which is in vast contrast to the process in Ireland. As of December 2013, only one CHP plant has been processed through Gate 3 (Eirgrid, 2013).

Due to issues of increased numbers of applications from conventional and RE generators, the Commission for Energy Regulation (CER) has had to review the process of offers for grid connection (CER, 2009). The CER decided that small, renewable and low carbon generators can be considered for connection outside of the GPA if they are deemed to be of 'public interest', which is defined as projects including diversity of fuel mix, predictability and power system support, environmental benefits, or if the project is experimental/research based (CER, 2009). The technologies that have been classified as being of 'public interest' are bioenergy, CHP, autoproducers, hydro, wave, solar and geothermal, up to 5MW, and are not subject to interaction studies (CER, 2009). Conventional plants above 5MW will still be subject to interaction studies, and if there are interactions found, the plant must remain in the queue (CER, 2009). From the TSO's program of connections 2010-2023, there are 19 projects which have met the criteria and have been granted connection outside the GPA, with two listed as CHP plants and one small scale residential DH system in Elm Park, Dublin (Eirgrid, 2010). In comparison to the GPA, the typical timeline for receiving a connection offer outside the GPA is 90 days (SEAI, 2008).

The lack of large scale efficient CHP systems in Ireland is further compounded by the regulations against private wire networks, with electricity generated only allowed to be used on the premises, or exported to the grid (SEAI, 2008). Any generators with a maximum export capacity greater than 10 MW are obliged to participate in the spot market. Ireland is one of the few countries in Europe where the transmission system and distribution system are owned by the same state owned company, but both are operated as separate entities under the EU unbundling regulations (Ruester, et al., 2013). The Electricity Supply Board (ESB) and its subsidiaries comprise a vertically integrated business which dominates the Irish electricity sector, and own more than 37% of the generation capacity (The Competition Authority, 2010), and so, due to its dominance, and the fact it is state owned, it has a lot of power and influence in the decision making process regarding national energy regulations. For system innovation in terms of the energy structure in Ireland, there needs to be political and institutional willingness and capability to break with the 'mono structure' of the current electricity supply and enter a combined DH and power supply structure (Hvelplund & Lund, 1998).

DUBLIN DISTRICT HEATING

At the moment there are some small scale DH projects in Dublin, the majority of which are single use stand-alone residential complexes, with the only large scale DH system at Ballymun now decommissioned. There have been analyses of the potential for DH in Dublin, and it is found to be technically, economically and environmentally feasible, according to Olivier Galliot of RPS consultants (Galliot, 2007). RPS, along with Danish consultants COWI, carried out the '*District Heating for Dublin: Feasibility Study*' in 2007. This feasibility study states that in spite of the mild Irish climate, heating is required for several months of the year and for hot water all year round (RPS/COWI, 2007). The feasibility study also found that "*Dublin City has the size and concentration of large buildings to host a large district heating system*" (RPS/COWI, 2007, p. vii). The scenarios studied in the report showed positive economic results in all cases, including a scenario of a citywide DH network, but all scenarios are sensitive to price of heat supplied to the network and price of heat sold (RPS/COWI, 2007). These conclusions are in contrast to the conclusions of the SEAI study discussed at the beginning of this chapter, showing that while the development of DH on a national scale may face 'insurmountable' barriers, the feasibility of DH can become positive when studied at a regional level.

One of the scenarios analysed in the RPS/COWI report examines the large DH project planned for the docklands area of Dublin City, called the 'Dublin District Heating Project'. This area has gone through major redevelopment over the last 10 years, and was identified by Dublin City Council as an ideal location to integrate a large scale DH system into the city's infrastructure, and would be the largest DH project in

Ireland. The plan was to include an incineration plant as the heat source for the system, which would also help to meet the city's waste disposal targets. The project is estimated to save over 150,000t CO_2, based on 90MWth and 50MWe production (Galliot, 2007). The DH pipelines were installed at the time of development in order to allow connection to the planned DH system when a heat source becomes available. This kind of forward planning in new developments will reduce the barriers for DH in future, as the municipality ensures the infrastructure is in place from the beginning and makes the development DH ready. This has unfortunately only been the case in this particular area of development, and there are no plans for future DH schemes or infrastructure in the regions current planning guidelines (The Regional Planning Guidelines Office, 2010). Correspondence with an officer at the Regional Planning Guidelines (RPG) office confirmed this, and the officer added that "(planning guidelines for DH) *has not occurred as an issue at regional level*" (Bradley, 2014). The NREAP, article 13(1), states that planning authorities provide guidance documents for renewable energy installations for electricity and heat, but this is clearly not the case for DH schemes. This is in contrast to the Greater London Authority, who released a 'District Heating Manual for London' in 2013 to provide guidance for the development of DH in London (Greater London Authority, 2013).

The Dublin DH Project has been ongoing over the last 10 years, and the council have spent over €96m on the €500m project to date (Keegan, 2014). The project has suffered setbacks of late due to contractual issues regarding the incineration plant. Two complaints were sent to the EU Commission claiming the public-private partnership contract, between the municipality and the energy companies Covanta and Dong Energy, breached EU regulations on state aid and procurement (Keegan, 2014). Very recently (8th May 2014) the EU Commission cleared the project of breaching the rules on state aid, with the public procurement complaint still being processed (RTE News, 2014). If the remaining complaint goes against the project, then the Dublin City Council manager has stated the project will be cancelled, and the council would lose the €96m already invested (RTE News, 2014). There have also been many reports on the lack of business plans for the future operation of the plant, many protests by local residents against the incineration facility, and local politicians objecting the project. Incineration plants are not received well in Ireland due mainly to environmental concerns of emissions, traffic congestion caused in area and the general 'not in my back yard' protests. These protests and legal issues have seen the public lose confidence in the municipality's ability to provide a successful energy project and may give a negative view of DH in the area due to the association with incineration.

The feasibility study for DH in Dublin gives a description of the only commercial DH plant that was operational at the time, which was installed in the Dublin City Council's Civic Offices in the centre of the city (RPS/COWI, 2007). The system was owner operated by Bord Gais[3] and provided heat for the offices, three nearby hotels, and private and social housing. This scheme has since ceased operation, and there are no publicly released details as to why the system is not in use. The RPS/COWI report states there were issues during its operation regarding metering and contractual issues, and these are likely the causes as to why the project did not succeed. Considering the local authority was heavily involved and the scheme was not successful, it questions the ability of the municipality to deliver other planned DH projects.

DUBLIN DISTRICT HEATING WORKSHOP

There was a DH workshop hosted by Codema in Dublin on the 21st of May 2014[4] (Codema, 2014), as outlined in the methodology chapter under 'Stakeholder Discussion'. The purpose of the workshop was to bring together the stakeholders involved with DH in Ireland, and discuss what is hindering its development. The key-note speaker was from a DH research group in Aalborg University, David Connolly, who informed the audience of the myths surrounding DH. The work carried out by the DH research group showed that there is enough surplus heat in Europe to meet all heat demands, and in Ireland 30% of heating energy requirements are in areas of high heat density and therefore suitable to

[3] Bord Gais is the state owned gas supplier and owner of the national gas pipeline network
[4] Proceedings of the conference are currently (May 2014) being prepared for publication by Codema

DH. Connolly showed how DH is not just a local solution, but is an integral part of the overall energy system, and can help to integrate higher amounts of RE into the electricity grid through thermal storage. This is an important factor for Ireland, as they seek to integrate higher levels of wind resources, and have few options for storage. Connolly sought to dispel the myth that only cold northern parts of Europe need heat, and presented a map which shows the heat demands in Europe only vary up to 20% from the southern parts of Europe like Spain, all the way to the northern parts of Sweden. This would seem to contradict some of the findings in reports already mentioned in this chapter and the government's stance on DH, which cite Irelands' mild climate as a barrier to DH.

Some case studies of DH were also discussed during the workshop. The DH system being developed at the Grangegorman site in Dublin City will provide heat and electricity to the college campus on the grounds, and heat to the other facilities on the site, such as a small hospital, student accommodation etc., and will be one of the largest DH systems developed in Ireland when it is complete. The first barrier mentioned by the planners was finding funding for the upfront costs of DH, with numerous separate buildings coming online at different stages of the development. The developers carried out a study of what was more beneficial for their needs, a centralised energy system or dispersed individual units, and the centralised system was found to be the superior solution. The centralised system will combine CHP, boilers and generators in an energy centre to feed all buildings on site, with individual solar thermal and PV solutions on each individual building contributing to their own needs. This DH energy system is designed as a stand-alone site, considering only the sites energy needs in isolation. The developers did not consider the option of selling to the grid, as the college has a large enough electricity demand to use all electrical power produced onsite and the system is not deemed to be operating on a private wire network.

The developers at Grangegorman are currently deliberating which fuels and production units to use, and have examined six scenarios of combinations of boilers and CHP units fuelled by gas, biomass or Pure Plant Oil (PPO), but did not consider biomass fuelled CHP. The study allocated weightings to numerous factors, including those surrounding sustainability and security, but was heavily weighted toward capital and fuel costs. The outcome of the study showed the 'gas CHP & gas boilers' option scored highest according to their applied weighting factor, which is expected when the study is heavily weighted on capital costs. This combination of production units is planned to be implemented in phase 1 of the development. A second study of the same options was carried out, and instead heavier weightings were allocated to CO_2 emissions. This study found the 'PPO CHP & PPO boilers' option scored highest, with use of woodchip boilers coming second due to lower scoring on boiler life cycle and requirement for continuous attendance. This option of production units is now considered, but not finalised, for implementation in future phases of the project development.

There were concerns raised as to the amount of traffic which would ensue if there were to be large number of deliveries of woodchips required, as the site is just on the outskirts of the city centre. The Grangegorman site ruled out the use of wood pellets, citing that there was no sustainable wood pellet supply in Dublin, and the fuel would need to be imported. This point was countered by the former president of the Irish Bioenergy Association, Tom Bruton, citing Ireland had several wood pellet production facilities, and urged the developers at Grangegorman to reconsider their stance on the use of woodchip and wood pellets in the proposed DH system. Mr.Bruton also stated he has had experience with running heating plant on PPO fuel, and believes it is not a sustainable fuel for thermal use. These disagreements show there is a lack of harmonised knowledge regarding the current stance of the biofuels market in Ireland.

The DH system developed by Tralee County Council in Kerry, south of Ireland, is successfully implemented, and provides heat to a community centre and a group of social housing in the area, under the Mitchels-Boherbee Community Regeneration Project. The system runs on two woodchip fuelled boilers, producing heat at a cost of €0.05/kWh, and supplies heat at a cost of €0.10/kWh. The scheme uses a 'pay as you use' pre-payment system, which addresses the issue of fuel poverty and allows the consumer to monitor and control their energy use. The average annual cost per apartment is €750 per year. There are plans to expand the system, and Tralee has an energy plan for the area mapping out future areas for development. This project is an example to other local authorities as to how an energy plan can be implemented successfully, although there was a significant amount of public funding available for the Tralee project.

Other issues raised during the stakeholder discussion revolved around the ownership structures of DH pipelines, financial guarantees, and the lack of finance available to cover large upfront costs.

To look at what is inflicting the progression of large scale DH in Dublin, this report will take an in-depth focus into a planned large scale DH network in the south of Dublin. This will comprise of a techno-economic feasibility study, which will aim to show the costs and benefits, from a societal viewpoint, involved in implementing a DH system in Ireland.

CASE STUDY: SOUTH DUBLIN COUNTY COUNCIL DH PROJECT

The DH system under analysis in this report is the planned network by South Dublin County Council (SDCC) in the town centre of Tallaght, South Dublin. The proposed system will link the heat demands of several large existing heat consumers; a large regional hospital, municipal buildings, a large shopping mall and a college. The unique features of this feasibility study, in comparison to other DH studies carried out in Ireland, are it is an in depth techno-economic hourly energy system analysis, using well established Danish DH analysis software, and analysing a retrofit project where the real heating demands are known and not estimates. The proximity and area of these buildings are shown on the map below in Figure 3. These buildings are included as they have high heat densities and have all shown an interest in connecting to a potential DH network, but there are many other large heat consumers in the area which could potentially connect to the grid in the future. The heat density in the area shown is 93.1TJ/0.17km2, or 549TJ/km2, and could potentially be higher if the heat demands between the outlined areas were also taken into account. Heat densities which would be considered highly feasible for DH systems from a Danish perspective are heat densities of 150TJ/km2 and above (Euroheat & Power, 2013), meaning this area is a very attractive prospect for DH.

FIGURE 3: AERIAL VIEW OF PROPOSED DH CUSTOMERS

There may be costs incurred by the need to adjust the existing heating systems in the consumer premises in order that the flow and return temperatures of the new DH system provides the correct amount of heat. This is the case when the DH system operates at lower temperatures and the existing systems are designed for higher temperatures. To maximise the efficiency of a DH system, the return temperatures would be much lower than those of a typical existing wet system installation, and so to be incorporated effectively, the heat transfer needs to be maximised (COWI, 2012). In buildings with wet systems this usually involves some combination of installing radiators with larger surface areas, adjusting the building management settings, and changing setting on bypass valves (COWI, 2012). In Ireland there are typically many individual electrical heating systems installed in apartments, which would incur much higher costs to retrofit to DH, but would benefit from higher savings due to the high price of electricity, even on night rate. In large retail and office buildings there may be Air Handling Units (AHU) installed, which can potentially be retrofit to connect to DH, but this depends on space available in the AHU to change the heating coils (COWI, 2012). The problem of retrofitting can be overcome in other ways, such as allowing for higher return temperature heat so the existing systems can operate as normal, or put in place heat saving measures at the same time as the DH system so there will be a lower demand and a lower supply and return temperature will suffice (Connolly, 2014). Typically costs for the consumer side meter and heat exchanger will be met by the consumer, and this case assumes all measures will be taken in order to reduce the need for retrofit of existing heating systems and therefore reduce further costs to customers.

If a CHP unit is to be a part of the DH system, then a connection to the grid is needed. In Ireland the regulations forbid that electricity can be sold over a private wire network, and can only be used in the onsite premises (SEAI, 2008). The municipal buildings do not have a large enough electricity demand to meet the electrical output of a CHP unit sized to meet the heat base-load of all consumers, and there is potential to take advantage of REFITs for biomass CHP, so in this case it is most feasible to connect to the grid. There is possibility to provide the municipal building with electricity to cover their demand, and sell the excess to the grid, the feasibility of which will also be analysed. The position and capacity of the nearest distribution network connection point should be investigated in order to estimate the potential costs of connection to the network. Having electricity generation onsite is of particular interest in this case, as the municipality buildings have recently gone through an assessment which recommended a back-up generator be installed for security of supply. This could instead be provided by a CHP plant which could switch over to provide these buildings with electricity directly when needed, and also negate the need for extra investment in diesel fuelled back-up generators.

There are potentially sites in this area which dump surplus industrial heat, which could contribute to the DH system, but an investigation into this is outside the scope of this study. The site has had two previous analyses carried out in order to show the feasibility of a DH system, neither of which mentions the potential use of industrial waste heat. The first report looked at connecting the hospital and municipal buildings to a DH network which would be powered by a biomass boiler, sized at 50% of the peak demand, and utilise the existing gas boilers to cover peak demands. The analysis resulted in a cost of over 7c/kWh to the consumer, which was 40% higher than the costs the consumers were paying at the time of the study, and therefore deemed unfeasible. The study only considered one combination of units, and did not analyse the operation on an hourly basis so the peak hourly demand was estimated.

The second report looked at heating the same buildings as shown in Figure 3 above, with either biomass boiler or CHP. There were some fundamental errors made from the outset; the size of the CHP units were based on adding the electrical and heating demands of all buildings, and dividing by total hours in the year, and assuming a uniform 24 hour demand. Sizing the units in this way would assume the CHP produces equal amounts of electricity and heat at the same time, which is inaccurate, assumes the electricity and heat demand coincide at all times, which is highly unlikely, and assumes the electricity produced can be delivered to all the consumer premises on a private wire network, which is illegal under Irish regulations. This calculation method will also result in inaccurate sizing of peak load units. The study does not consider a thermal store for the site meaning the CHP would not perform optimally in response to market conditions. The results of the calculations in the study led to a CHP size of 5MWe, which can be compared to the results of the analysis in this case study to see how the results vary.

An analysis of these previous studies leads to another barrier to implementing DH with CHP in Ireland; there is a lack of knowledge and experience of the systems. Many CHP units are over/under sized, and may be the reason as to why so many CHP units are installed but not operational, as mentioned in the introduction. Other potential opportunities and barriers will be discussed later in this report.

The inputs used in this case study that are particular to this case study site are the heat density of the area and the heat demand profiles of the consumers. Therefore the results of this study are applicable to many other potential sites in Ireland with similar heat densities and demand profiles.

TECHNICAL AND FINANCIAL INPUTS FOR DH SYSTEM MODEL

The following is a description of the data which is input into the EnergyPRO software in order to represent, as accurately as possible, the conditions surrounding a proposed DH system at the site previously described. The initial settings are described below, representing present conditions, however inputs are adjusted later in the analysis in order to show how variations affect the technical feasibility and economic viability of the system.

TIME SERIES

The time series used are the hourly ambient temperatures and hourly electricity market prices from the Single Electricity Market Operator (SEMO). The ambient temperatures are taken from weather data measured in south Dublin, accessed through the Climate Forecast System Reanalysis (CFSR), the data from which is based on many data sources, such as weather stations, weather balloons, airport reports etc. The year 2010 had the most complete data set, and was therefore chosen for the model, but various annual temperatures will be tested in the model to analyse the impact of varying annual weather conditions. The temperatures are linked to an index which follows the Intergovernmental Panel on Climate Change (IPCC) prediction of a 0.4 degree increase in global average temperatures over the next two decades (IPCC, 2007).

The electricity prices are hourly historical prices for 2013, accessed from the SEMO online database of dynamic reports (SEMO, 2014). The latest full year of electricity prices is chosen, as the System Marginal Price (SMP) varies with the type of generation plant supplying the grid, with more renewables, particularly wind, lowering the SMP, and therefore the latest prices will represent the most up to date mix of generation on the grid. When biomass CHP units are considered, the electricity price is adjusted to include the REFIT guaranteed payment for large biomass CHP units of €125.84/MWh. For comparison, the average SMP in 2013 was €65.25/MWh, so the REFIT is nearly double the average hourly price.

INDEXES

There are indexes used which have been created in order to apply forecasted changes over the 20 year project period analysed. Those previously mentioned are the predicted 0.4 degree increase in global temperature, and the predicted increase in gas prices. Inflation is set at 2% as indicated by the Department of Public Expenditure and Reform (DPER) for public sector budgets (DPER, 2013). There have been indexes included in order to apply decreases in heat demand over the period analysed, which are taken as the targets set nationally of 33% for public sector, and 20% for private sector, to 2020, and it is assumed that these targets will be applied to both heat and electricity evenly. It is also assumed that no actions have been taken to meet these reduction targets before the beginning of the project, and so the reductions are likely overestimated for the period to 2020, but will be partially offset by the fact possible further reductions after 2020 are not taken into account.

FUELS

The fuels analysed for use are natural gas, wood chips, wood pellets and electricity, and the energy content of each is entered (source of energy content used (SEAI, n.d.)). Oil and coal are not considered due to price and emission levels respectively, and no other fuels are considered as there are no perceived socio economic advantages from using other fuel sources.

DEMANDS

There are four heat demands to be connected to the DH system in this case study; a large hospital, municipal buildings, a large shopping centre, and an educational facility. The hospital has the largest annual heat demand in the system, with 85% of this demand said to be providing space heating, and 15% water heating, the split is taken from typical hospital energy data from SEAI (SEAI, n.d.). The demand is 24 hours a day, 7 days a week, and set to depend linearly on hourly ambient temperatures (from the time series mentioned previously), with reference temperature set at 15.5°C. This demand is also linked to follow the index describing 20% reductions in demand to 2020.

The SDCC buildings have been grouped together as one demand, as they are all in the same area and have similar demand profiles. The municipal buildings have an annual heat demand which again fluctuates depending on external weather conditions. Also overlapped onto this weather dependent demand profile is a fixed profile of demand from Monday to Sunday, showing a typical demand profile for a municipal office building during an average working week. This average weekly demand profile is calculated using actual monitored hourly data readings from the Dublin City Council offices, which will closely represent the typical demand pattern of the SDCC buildings, having the same general occupancy hours. The demand also follows an index of reduced demand over the period studied, following the index representing the public sector demand reduction targets.

The shopping centre heat demand was calculated slightly differently to the others, as retail units in Ireland use high levels of electrical heat sources, thus gas consumption alone could not be used as the total heat demand. Due to lack of more detailed data, the thermal requirement of the centre is taken as 75% of the total energy demand, as this is typical for services sector in Ireland (SEI, 2008). Again, like the others, the demand is linked to a reducing demand of 20% to 2020 and to external weather conditions, with 20% said to be for hot water requirements, and the fixed demand profile is based on the weekly opening hours.

The college's annual heat demand is linked to the same types of time series and indexes as mentioned for other demands. All demands are said to be connected from the beginning of the project.

Losses in the DH network are input as a demand, and equal to 15% of the total heat production. This percentage is at the higher end of the scale of average losses in a DH network given by the Danish Energy Agency (DEA), but taken as a worst case scenario given the lack of experience of running and building DH networks in Ireland. The final demand included is an electrical demand for pumps used in the DH grid. Typical MWh/TJ/yr figures are used to calculate the energy required, sourced from the DEA (Danish Energy Agency & Energinet.dk, 2012), and reduces with reduction in heat demand over time.

ENERGY CONVERSION UNITS

The energy units are limited to HECHP and boilers, due to current supports for the use of HECHP, and the low cost of boilers for back-up power. The use of heat pumps in this case is not included due to lack of geothermal data available and no water sources at the location of the system. Solar thermal and incineration are not options for this particular site due to the geographical restrictions, but could be feasible at another location nearby if the system is to be expanded.

Fuels for each unit, and combination of units vary with each scenario analysed. Inputs for energy conversion units are fuel used, non-availability periods (for annual scheduled maintenance) and power curves. The power curves dictate the efficiency of the unit at different loads. The size of the units is dependent on the average hourly heat production and the peak heat production in an hour over the year, and both of these figures are obtained through the software as an output once all specifications for demands & losses are input. The main unit should be sized to approximately 120% of the base-load and a boiler used for back-up, sized at 120% of peak production (Connolly, et al., 2014). The base-load in this case is approximately 3.4MW (29.7GWh total annual demand divided by total hours), and peak demand is 9.6MW.

The efficiency of the gas CHP unit in this analysis is taken as being at the higher end of the scale quoted by the DEA, which is 86% (54% heat and 32% electricity production), as this coincides with the average efficiencies of CHP units in Ireland (SEAI, 2012 (Update)). The gas CHP unit is assumed to be a Single Cycle Gas Turbine (SCGT) with heat recovery boiler, due to the small heat production required for the base-load of the system and Combined Cycle Gas Turbines (CCGT) not common in this size, also, a SCGT can start/stop within minutes and therefore better suited to operate at market conditions (Danish

Energy Agency & Energinet.dk, 2012). It is important to note that this type of gas CHP unit is listed by the DEA as having a technical lifetime of only 10 years, compared to larger units which have a life expectancy of around 20 years. This lifetime is deemed to be very short, as a biomass unit of the same size is listed as having a 20 year lifetime, and the gas technology equivalent is more developed, therefore this analysis takes the lifetime of the gas CHP to also be 20 years[5].

In some scenarios the CHP unit is biomass fuelled CHP, and associated efficiencies and costs are taken from the DEA manual (Danish Energy Agency & Energinet.dk, 2012). The electricity to heat ratio of woodchip fuelled CHP units is lower than that of gas CHP, meaning for the same heat output, biomass CHP produces less electricity.

All electricity is sold to the spot market, due to regulations already mentioned. Very high efficiencies are not applicable to boilers in this case as, when used to cover peak demand, the majority of operational hours will not be at full load and there will be a higher than normal number of start-up/shut-downs. Therefore gas and biomass boiler efficiency is set to maximum 95% at full load.

STORAGE

There is a thermal storage unit included in the analysis in order to optimise the use of the CHP unit when operating according to the electricity market conditions. This storage capacity should be sized to approximately 6 hours of average heat production (Connolly, et al., 2014). The storage capacity for this case is 20.8MWh, which equates to a volume of 450m^3. The storage height, insulation thickness and thermal conductivity, and approximate temperatures at top and bottom of the tank are specified in order to calculate storage heat losses, according to external ambient temperatures. In this case the tank height is set at 9 meters (meaning approx. 8m diameter) and insulation thickness of 300mm with thermal conductivity of 0.037W/(m°C).

OPERATION STRATEGY

The operation strategy for this analysis has been optimised to minimise net production cost. This strategy takes into account all economic aspects of operating each unit, and operates the unit of least cost to meet the demand in each hour. This means that depending on the spot price for electricity, and if there are feed in tariffs available, it can be more or less economical to run one unit over another. The operation is also linked to the availability of the storage capacity at the time. In this study all production units are allowed to store and allowed to operate at partial load. The number of hours each unit is operating at full load is visible in the outputs and this setting can then be adjusted if the units are operating at partial load (and therefore lower efficiency) for longer than desired. This operation strategy is very sensitive to the price of fuel, spot market prices, O&M costs and efficiencies of the units.

ENVIRONMENT

The CO_2 emissions are calculated dependent on fuel consumption of each production unit. Biomass fuels are assumed to be CO_2 neutral, and emissions for gas are set at 0.2047kg/kWh (SEAI, 2013). Other emissions are possible to calculate through the software, but ignored as the amount of NO_X and SO_2 emitted depends on the extra environmental equipment installed on each unit, which is not analysed in this case.

ECONOMY

This section deals with investment related inputs. The currency is set to Euro and an index selected for inflation, which is set at 2%. The nominal discount rate applied is 6.6%, as advised by the DPER (DPER, 2013). A sensitivity analysis is carried out adjusting these figures to show how variations affect the

[5] The analysis was conducted using both 20 year lifetime and 10 year lifetime. The results show the 10 year lifetime changed the economics of the scenarios which use this type gas CHP, but not significantly enough to change the overall results.

economics of the project. Outputs attained from these figures are Net Present Value (NPV) and Internal Rate of Return (IRR).

REVENUES

The revenues in this analysis are attached to the sale of heat, sale of electricity and standing charges. The sale of electricity is based on the hourly price on the spot market for 2013 (as described under time series). The REFIT is applied to bio-fuelled CHP units according to prices given by the DCENR, and are assumed to be extended past the 2030 deadline to the end of the production unit lifetime in 2033. The initial sale price of heat is set to the lowest price of gas currently paid by the consumers, minus VAT, and indexed to increase with inflation. The initial price is therefore the same as commercial delivered gas rate in Band I3, €38.94/MWh. The revenues from electricity sold to the spot market are linked to an index which follows forecasted gas prices (sourced from World Energy Outlook (IEA, 2013)) and inflation, the reason being the Irish price of electricity follows the price of gas closely due to the volume of gas fuelled generators on the grid (just over 50% of generation capacity in 2014 is gas fuelled).

Annual standing charges are priced in order to cover all annual O&M costs, and divided according to heat demand required by each consumer, which results in costs to the consumer of approximately 20% of annual heating costs. This is additional to the price quoted above charged per MWh, and should approximately represent the same costs incurred by current O&M of individual units.

Up front connection fees for consumers have not been included in these calculations, but may be relevant if the project needs to reduce loan costs. Potential capacity payments from the spot market operator are not included due to lack of detail on payments that would apply in this particular case.

OPERATION EXPENDITURES

The commercial costs of fuels quoted by the SEAI for 2014 are input into the model (SEAI, 2014), these prices are delivered costs and therefore take into account all levies and standing charges. These latest prices show that wood chip fuel, at €0.039/kWh is cheaper than gas at all commercial price bands up to the highest I4 Band rate (consumption above 27,778MWh/yr) where gas is less than 4c/kWh. Wood chip prices are continuing to fall, with a 2.6% price decrease since January 2013 (SEAI, 2014). Wood pellet fuel still retains a high price at €0.056/kWh, meaning it is only competitive with gas for customers who are in the lowest band rate, Band I1, where consumption is below 278MWh/yr. Gas Oil is over 10c/kWh, while coal is at a very low price of just over 1c/kWh, but is not considered due to the emission levels. Electricity, even at night rate of 7.75c/kWh, is not competitive with other fuels for heating purposes. The main fuels considered in this analysis are therefore gas and biofuels, the latter particularly, due to the FITs available for electrical production from bio-fuelled generators, and of course the environmental and sustainability benefits.

It is assumed there is VAT relief on imported fuel; there is no regulation or guidelines available for the provision of heat because a market does not exist. The issue of tax is currently being discussed by the SEAI, as part of the development of the National Energy Services Framework, who are in the process of consulting with an accountancy firm for advice on the setting of specific rules and guidance regarding VAT for biomass and CHP projects (Ryan, 2014). In Denmark, municipalities carry out DH feasibility studies without considering VAT, as they offset the cost of VAT on imported fuel by collecting the VAT from customer bills (Dyrelund, 2014).

The operation and maintenance costs (fixed and variable amalgamated) are calculated at a price per MWh for each generation unit, as quoted by the DEA (Danish Energy Agency & Energinet.dk, 2012). The O&M associated with the DH network itself is dependent on the total heat demand, and are calculated using DEA figures given in €/TJ/yr.

Carbon Tax is charged for gas used for boilers and CHP units. The rate of carbon tax for gas used in boilers is €4.10/MWh, and gas used in CHP units is assumed to qualify as fuel used in HECHP units, and therefore only subject to €0.54/MWh (the difference is given as a tax rebate) (Irish Revenue Commission, 2013). The delivered cost of gas excluding any carbon tax is €0.0348/kWh[6].

INVESTMENTS

Investment costs and average lifetimes for generation equipment, thermal storage units and the DH network itself are calculated based on data given for 2015 from the DEA (Danish Energy Agency & Energinet.dk, 2012). The prices used include all costs related to the physical equipment, engineering, procurement, construction and infrastructure connection costs (electricity, gas, water etc.) (Danish Energy Agency & Energinet.dk, 2012). Decommissioning costs are assumed to be offset by the residual value of the assets. The prices are predictions for 2015, based on a 2011 price level.

These investments are set to depreciate linearly over the specified lifetime. The costs for grid connection are estimated (due to lack of information on nearest grid connection point) based on standard costs given by the Irish DSO, ESB Networks (ESB, 2013). It is assumed that the energy centre, which will hold all the generation units and storage, will be based on land already owned by the municipality, as planned, and therefore no site purchase costs are considered. Fees for administration and applications for grid connection are taken into consideration.

The costs associated with the DH network are based on a conventional design, which would include high flow/return design temperatures, and utilising twin pipes to reduce losses. The price of the individual heat exchangers and meters on the consumers own property are not accounted for in the investment costs as these costs are assumed to be paid by the consumer.

FINANCING

It is assumed that a loan will be required to cover the cost of investments. An approximate interest rate for a business loan of €10m over 20 years from an established Irish financial institution is quoted at 4.35%, and so has been set at this level initially. Grants for RE investments could also be considered, such as the funding available through the SEAI's Better Energy Communities Scheme.

TAXATION

Income tax is not taken into account in this study as the company is assumed to be run as a not-for-profit organisation by the municipality.

[6] It is assumed the SEAI price for carbon tax is based on net calorific value.

RESULTS OF THE TECHNO-ECONOMIC ANALYSIS

There are 7 scenarios analysed, using the inputs described above, with differing combinations of production units. Table 1 below shows the combinations of units in each scenario. The reason for including two boilers to cover the peak demand in some scenarios is so the cheaper and renewable biomass fuel can be used to cover most of the peak demand, but restricted in size as biomass boilers have much higher investment costs than gas boilers per MW installed. In all scenarios, the heat demand is met at all times, meaning the units are correctly sized to deal with demand in any hour at all times of year; during peak winter hours and when units are out of operation for scheduled maintenance.

The results of the scenarios are appraised under financial, technical and environmental indicators. The scenario which scores best under these indicators is then shown in detail and subjected to a sensitivity analysis.

Unit Combination in Each Scenario Examined						
	Baseload 4MW				Peak 9.6MW*	
Project	Gas CHP	Biomass CHP	Gas Boiler	Biomass Boiler	Gas Boiler	Biomass Boiler
Scenario 1	X				X	X
Scenario 2		X			X	X
Scenario 3		X				X
Scenario 4		X			X	
Scenario 5				X	X	
Scenario 6			X		X	
Scenario 7	X				X	

TABLE 1: UNIT COMBINATION IN EACH SCENARIO ANALYSED

ANALYSIS OF SCENARIOS

The results show the choice of unit combination is crucial to economic feasibility. Firstly, Table 2 shows the results of a financial appraisal for each scenario. As can be seen, only one scenario has a positive NPV and is paid back within the lifetime of the production units, which is Scenario 4; the combination of biomass CHP and gas boiler for peak demand. The reason this scenario is more profitable is the combination of the lower investment costs of a gas boiler over a biomass boiler, the REFIT for electricity produced by biomass CHP, and, to a lesser extent, no carbon tax associated with the use of woodchip fuel and the lower cost of woodchips over gas per kWh. The IRR is 7.5% and has a payback period of 15 years. The carbon tax makes little difference to the use of gas CHP over biomass fuelled CHP, as there is tax relief for gas CHPs deemed to be HECHP. Without the REFIT, the NPV for scenario 4 drops to €-4.9m, and the gas CHP combination in scenario 7 becomes more favourable, albeit by a small margin.

Scenario 1 has very low NPV, due to a combination of no feed in tariff, the high investment costs of the biomass boiler, and the higher price for gas compared to woodchip per kWh. Scenario 2 changes the gas CHP to a biomass CHP, and keeps the same peak units, and the resultant NPV is not far from positive, due to the REFIT being applicable. When the peak demand is met by only one biomass boiler in scenario 3, the NPV decreases due to the large investment costs as a biomass boiler is eight times the price of a gas boiler per MW. Scenario 5 and 6, which investigate the feasibility of using only boilers, with no CHP units, also have large negative NPVs. Overall, it is the REFIT and investment costs which have the largest impact on the feasibility of one scenario over another.

Financial Appraisal of Each Scenario			
	Project Lifetime (20 years)		
	Financial Indicators		
Project	NPV (all payments)	Payback (yrs)	Total Investment (000s)
Scenario 1	-€6,515,215	not within Lifetime	10280
Scenario 2	-€645,103	not within Lifetime	11520
Scenario 3	-€4,624,998	not within Lifetime	15250
Scenario 4	€2,286,864	15	8530
Scenario 5	-€8,039,836	not within Lifetime	6190
Scenario 6	-€5,792,794	not within Lifetime	3340
Scenario 7	-€4,280,033	not within Lifetime	7240

TABLE 2 FINANCIAL APPRAISAL OF EACH SCENARIO

The tables below in Figure 4 show some of the technical and environmental outcomes of each scenario analysed. The first table shows the results pertaining to year one of operation, and the second table shows the results of the last year in the analysis, year 20, as the operational aspects change over the 20 year period with decreasing demand, increasing prices etc. The third table shows the emissions relating to each scenario and how they change over the lifetime.

Technical and Environmental Appraisal of Each Scenario												
	Year 1											
	Operational Hours			% Annual Demand		Elec Exported	Turn ons			Fuel Consumption MWh		
Project	CHP	Boiler 1	Boiler 2	CHP	Boiler(s)	MWh/year	CHP	Boiler 1	Boiler 2	Gas	Woodchips	% RE
Scenario 1	4089	5137	363	49%	51%	8779	555	333	106	27666	15668	36.16
Scenario 2	8387	2663	135	84%	16%	7986	19	101	12	197	36859	99.47
Scenario 3	8387	2469	-	84%	16%	7986	19	104	-	0	37069	100.00
Scenario 4	8387	2469	-	84%	16%	7986	19	104	-	5062	32007	86.34
Scenario 5	-	8422	2399	0%	100%	0	0	2	97	5062	26267	83.84
Scenario 6	-	8422	2399	0%	100%	0	0	2	97	31329	0	0.00
Scenario 7	6146	3362	-	75%	25%	13421	465	254	-	49743	0	0.00

	Year 20											
	Operational Hours			% Annual Demand		Elec Exported	Turn ons			Fuel Consumption MWh		
Project	CHP	Boiler 1	Boiler 2	CHP	Boiler(s)	MWh/year	CHP	Boiler 1	Boiler 2	Gas	Woodchips	% RE
Scenario 1	2999	4766	150	45%	55%	6335	520	343	42	19841	13591	40.65
Scenario 2	8346	1233	51	92%	8%	6940	38	115	18	31	29738	99.90
Scenario 3	8346	934	-	92%	8%	6940	38	112	-	0	29774	100.00
Scenario 4	8346	934	-	92%	8%	6940	38	112	-	1901	27873	93.62
Scenario 5	-	8419	933	0%	100%	0	0	2	112	1901	22875	92.33
Scenario 6	-	8419	933	0%	100%	0	0	2	112	24776	0	0.00
Scenario 7	5499	2089		83%	17%	11698	526	275	-	40821	0	0.00

Lifetime			
	Environment		
Project	CO_2 (t) (Year 1)	CO_2 (t) (Year 20)	% decrease in CO_2
Scenario 1	5663	4061	-28%
Scenario 2	40	6	-85%
Scenario 3	0	0	-
Scenario 4	1036	389	-62%
Scenario 5	1036	389	-62%
Scenario 6	6413	5072	-21%
Scenario 7	10182	8356	-18%

FIGURE 4: TECHNICAL AND ENVIRONMENTAL APPRAISAL OF EACH SCENARIO

The technical aspects of importance are whether the CHP unit is covering the majority of the demand, where the back-up boilers typically amount to approximately 10% of total annual demand, and also, the number of turn-ons will affect the lifetime of the production unit and cause higher O&M costs. The amount of electricity exported will show which system contributes most to the grid and to the renewable content of the energy on the grid. The amount of renewable fuel in each scenario will indicate how sustainable the system is, how it contributes to security of supply and potentially how much revenue from fuels is retained nationally.

In terms of operational hours, the CHP units in scenarios 2, 3, and 4 are all equal as the REFIT for biomass CHP ensures the unit runs the majority of the time, which also means they have the same number of turn-ons which is very low at a total of 19 times in year one, which increases to 38 in year 20 due to reduced heat demand. These scenarios also have a high share of the demand met by the CHP unit, which is at 84% in year 1 and increases to 92% in year 20 as the unit meets more of the demand as demand reduces overall and the price of gas rises. The scenarios involving gas CHP units have much higher turn on rates as they switch according to a varying SMP and it is cheaper to produce heat by biomass boiler when the SMP is below a certain price. This also contributes to the fact the CHP in Scenario 1 only meets a maximum 49% of the annual heat demand, with back up boilers contributing the rest. The scenarios involving gas CHP do contribute more electricity to the grid in year 1, even without a feed in tariff, this is because the gas CHP units have a higher electricity to heat ratio, therefore producing more electricity for every MWh heat produced when compared to a biomass CHP unit. This is one of the benefits of gas over biomass CHP, along with the fact the gas CHP does not require large storage facilities for fuel deliveries.

In terms of emissions and renewable fuel use, scenario 3 scores best, with 100% of fuel use coming from woodchips, and therefore CO_2 neutral. This scenario therefore contributes most to renewable energy targets, emission reductions, and security of supply, and has lower operation expenditures due to lower fuel costs and no carbon tax. This scenario may become financially competitive with scenario 4 if either the price of investments for biomass boilers reduce or if there were grants available to contribute to investment costs.

A comparison of the currently installed individual heating system's investment and running costs for all consumers, compared to the total investment and running costs for all consumers if on the DH network are shown in Figure 5. Due to lack of data on the actual systems currently installed, there have been assumptions made regarding size and efficiency; it is assumed the units are gas boilers sized at 120% of peak load, and with 90% efficiency. The installation and maintenance costs of the DH heat exchangers at the customer premises are taken from the DEA (Danish Energy Agency & Energinet.dk, 2012). Investment costs for the consumer on a DH network include a heat exchanger, meter, and connection pipeline to the main network, but do not include any costs incurred by potential retrofitting needs.

Comparison of Consumer Costs			
Total Consumer-Side System	**Individual**	**DH**	**Difference**
Heat Demand MWh	25,864	25,864	
Investment	1,060,000	742,000	318,000
Annual Fuel/Heat Costs	1,262,434	1,208,000	54,434
Annual O&M	139,667	53,000	86,667
Total Annual Costs	1,402,101	1,261,000	141,101

FIGURE 5: COMPARISON OF CONSUMER SIDE COSTS; INDIVIDUAL SYSTEM VS DH CONNECTION

The difference in costs for the consumer shows that connecting to the DH network will cost €318,000 less in up-front investment and annual cost savings of over €141,000. It is worth noting that annual cost savings are not evenly distributed between all consumers as the shopping centre had higher individual system fuel costs for heat due to the use of electrical heating, and therefore see more savings from the DH system than the other users. These savings could be potentially higher if there are back-up units installed in the consumer's premises, the investments for which have not been taken into account, or if the current efficiencies are lower than 90%. The difference between the annual fuel and heat supply costs are based on the heating being provided at the same price per MWh as the consumers were already paying for gas, so this saving only really represents the difference in efficiency, with the heat exchanger assumed to be 100% efficient. There is potential that heat from the DH system could be provided at a much lower cost, which will be analysed in the sensitivity analysis later in this chapter. There is also the potential for the system to provide cooling loads to the consumers and save on individual cooling systems, but this is outside the scope of this study and is an area for further study.

The results of the overall analysis have therefore shown that, under short term, current market based economics, there is a DH scenario, scenario 4, which is feasible while retaining a competitive price for the commodity. The same scenario also has a large proportion of its fuel needs covered by renewable sources, which increases to nearly 100% by year 20, meaning very low emissions from the system over the period analysed. This biomass is most likely to be sourced from Ireland, which leads to a higher security of supply and more capital staying inside the country and contributing to the Irish economy. The customers will also benefit from lower fuel prices than they would have had traditionally when using individual gas and electrical heating systems, assuming the DH company is run as a not for profit organisation by the municipality. Comparing emissions to the current situation, the current total gas fuel consumed by the customers amounts to CO_2 emissions of approximately 5,280 tonnes annually, meaning scenario 4 offers between 80% and 92% emission reductions annually over the 20 year period. It is important to reiterate the proviso that there is no VAT on fuel imported for the provision of heat in these calculations, as stated in the inputs. If VAT is applied it will affect all scenarios in the same way, and so scenario 4 will still be the preferable choice, but will be less profitable.

DETAILED RESULTS OF SCENARIO 4

Some detailed outcomes of the analysis of scenario 4 are shown below, the full details are available in the Appendix A. Figure 6 shows how the heat demand reduces over time, with the targets for energy efficiency to 2020 taken into account. The effects of global warming are also included, but obviously have a much lesser effect. The chart also shows how this reduction affects the production units. The gas boiler is more affected by this reduction than the CHP, as the CHP has priority, and the reduction in electricity production is cushioned by taking advantage of the thermal storage facility. There is an option to ensure the electrical production is not affected by a drop in heat demand at all, which is to allow the system to dump heat through a heat rejection unit, but this option is not considered in this analysis. Heat rejection would lower the overall efficiency of the unit and it would therefore not be eligible to be registered as a HECHP. The reduction in heat demand could allow new demands to be introduced to the system without the need to increase the energy centre capacity.

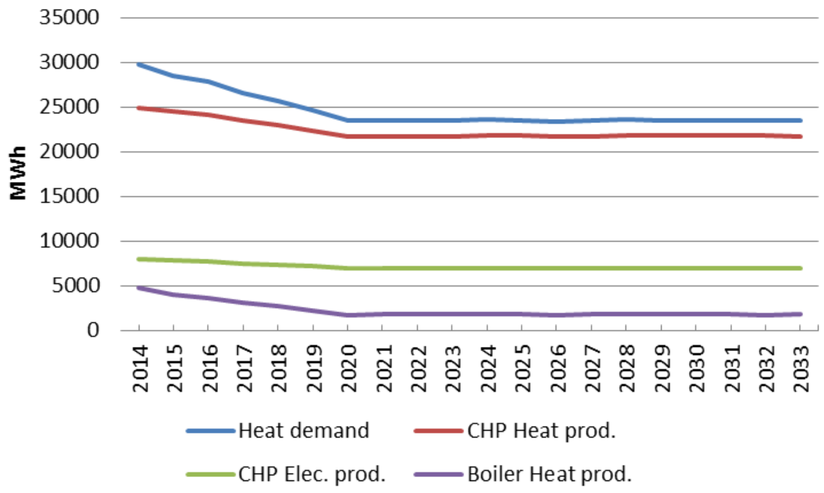


FIGURE 6: DEVELOPMENT OF HEAT DEMAND AND HEAT PRODUCTION OVER TIME

The production graphic in Figure 7 shows the theoretical hourly production of the energy units and use of the thermal store in the month of January in year 1. It also shows the conditions which affect the production and demand; the SMP (top graph), the ambient temperatures (second graph), and the hourly Net Production Cost (NPC) of each unit (third graph). The heat demand, which is the pink line on the fourth graph shown, is met by both CHP and boiler production in this particular month. As you can see, the red, representing the CHP production, covers the base-load demand, and the gas boiler meets the peaks. The boiler will operate at full load when possible, and fill the storage unit with heat surplus to requirements, but when the storage is full the production load of the boiler fluctuates to meet demand. The storage unit is used to meet the peaks above the base-load whenever possible.

The electricity production, seen on the fifth graph down, is fairly constant at full capacity, until such a time that the demand is below the base-load level and the thermal store is full. In year 1, the CHP operates at full load 75% of the time, with the majority of the remaining 25% being close to full load. In comparison, the boiler only operates at full load 25% of the time in the same year; however the current best available gas boiler technology still retains adequately high efficiencies when operating below full load capacity. The last graph on the figure shows the thermal storage capacity and the hourly content level, and it can be seen that the operation strategy takes full advantage of the stores capacity in the month of January.

FIGURE 7: PRODUCTION GRAPHIC OF JANUARY, YEAR 1, FROM SCENARIO 4

The annual fuel consumption in year 1 is equal to 10,000 tonnes of woodchips (wet), with a peak of 5 MW in an hour, and annual gas consumption of 5,000 MWh, with a peak of 10 MW in an hour. By year 20 the annual gas consumption drops by 62% to 1,900 MWh, and woodchip consumption reduces to a much lesser degree, by 13% to 8,710 tonnes. This means the initial size of woodchip storage unit will still be applicable to the requirements even after the reductions in demand.

A graphic of the operation strategy calculation for the month of January, year 1, can be seen in Figure 8. It shows the net heat production costs (NHPC) for each unit, with the CHP price varying according to the spot market price of electricity. As can be seen, the NHPC for the CHP is always lower than that of the boiler at any spot price, due to the guaranteed REFIT. Therefore the gas boiler is only used when the capacity of the CHP cannot meet the demand. The electricity balance price for equal NHPC between the two units is -€18.17/MWh.

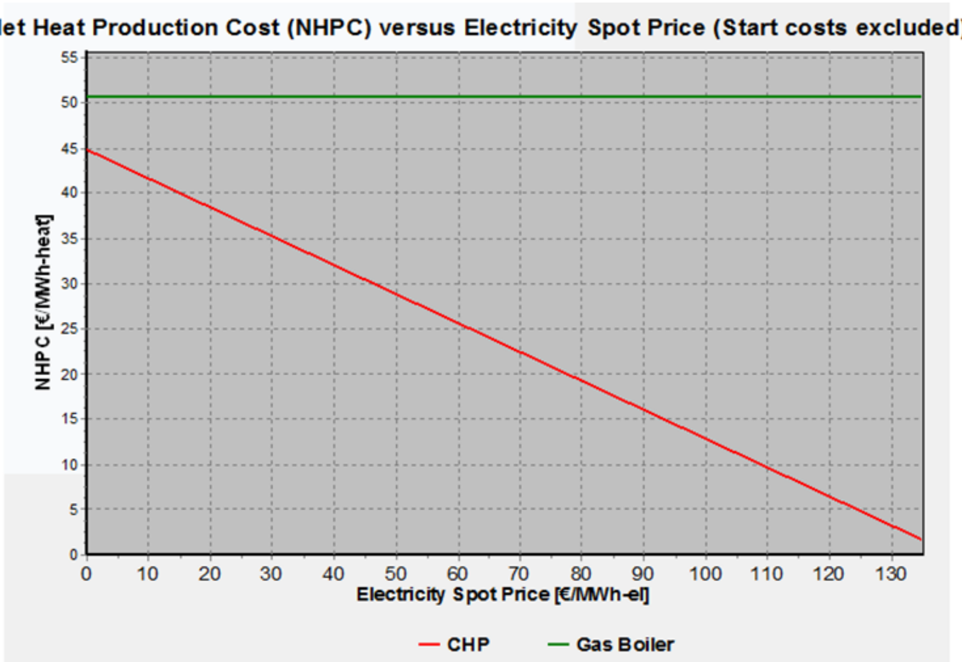


FIGURE 8: NET PRODUCTION COST VS SPOT PRICE; JANUARY YEAR 1, SCENARIO 4

For comparison, the figure below shows the same operation strategy employed in scenario 1 (gas CHP, gas & biomass peak boilers). Here it can be seen that it is cheaper to produce heat by gas CHP up to a spot price of €62/MWh, below which it is cheaper to produce heat by biomass boiler. The gas boiler becomes preferable when the spot market price is below €41/MWh. The comparison of this graph and that of scenario 4 above shows how the REFIT affects the NHPC and therefore the operation of the units.

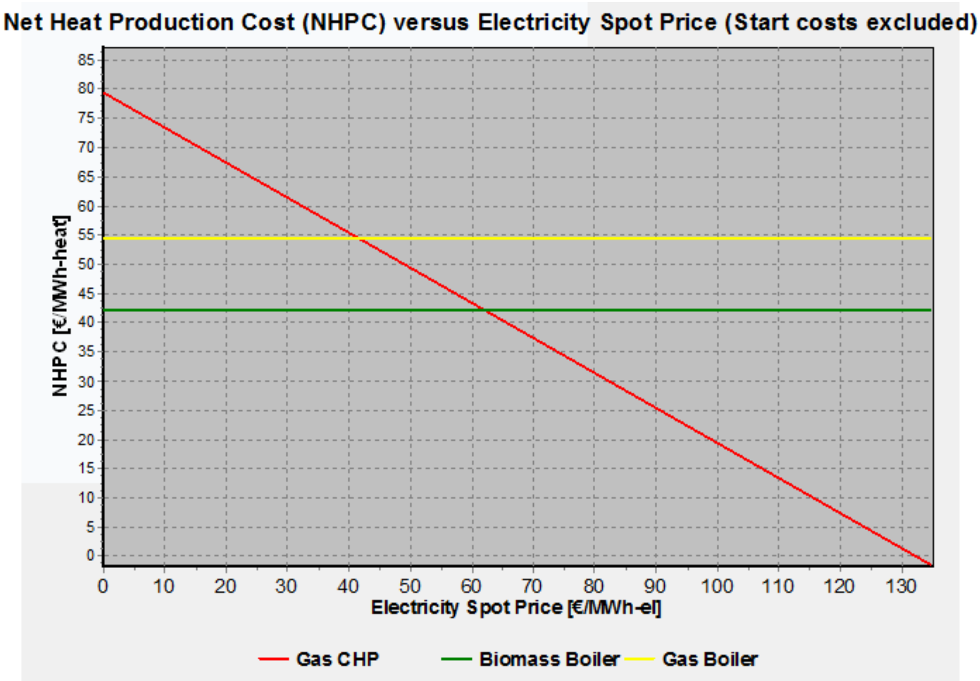


FIGURE 9: NET PRODUCTION COST VS SPOT PRICE; JANUARY YEAR 1, SCENARIO 1

Scenario 4 uses the REFIT to create lower heat production costs which will ultimately lower the cost of heat to consumers, while at the same time contributing green energy to the grid and replacing fossil fuels used for heating. Figure 10 below shows the difference in annual revenues from electricity exports with and without the feed in tariff. The FIT generates between 400 and 600 thousand euro additional revenue annually. The growth in the revenues over the period is due to annual inflation and rising gas prices, with revenues slower to rise in the beginning due to decreasing heat demand affecting the running hours of the CHP plant to the year 2020.

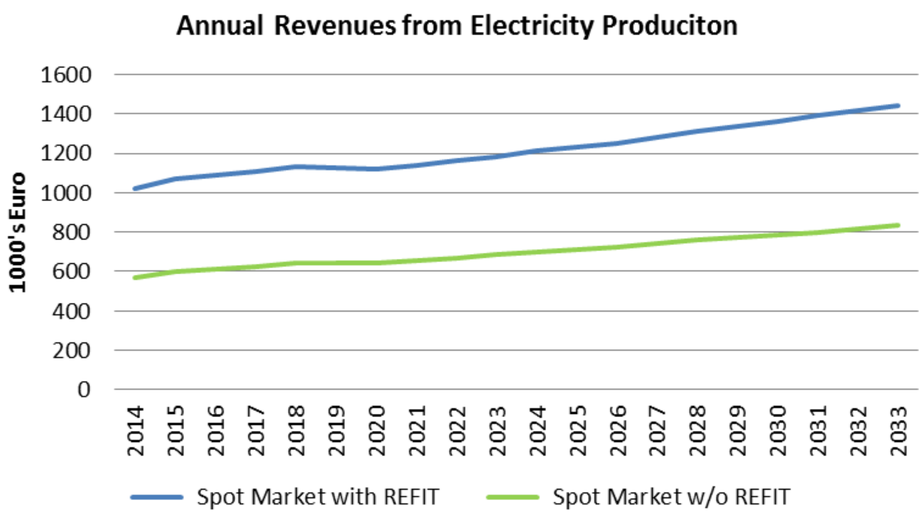


FIGURE 10: ANNUAL REVENUES FROM SPOT MARKET WITH AND WITHOUT FEED IN TARIFF

The DH system in Scenario 4 is further analysed to show how robust it is when subjected to a variety of market conditions, and results are shown in the following figures. The variables most likely to change are the price of woodchip fuel and the interest rate on the investment loan. The price of wood fuel is likely to decrease due to a potential merger of two large biomass producers in Ireland, Coillte and Bord na Mona, and due to availability of imports. The REFIT is guaranteed up to the end of 2030, with possible extension. Figure 11 shows that the NPV of all payments remains positive with a rise in discount rate above the advised 6.6% rate, only lowering by 16% when at 8.6%, but the NPV of net cash from operations and investments becomes negative at approximately 7% discount rate.

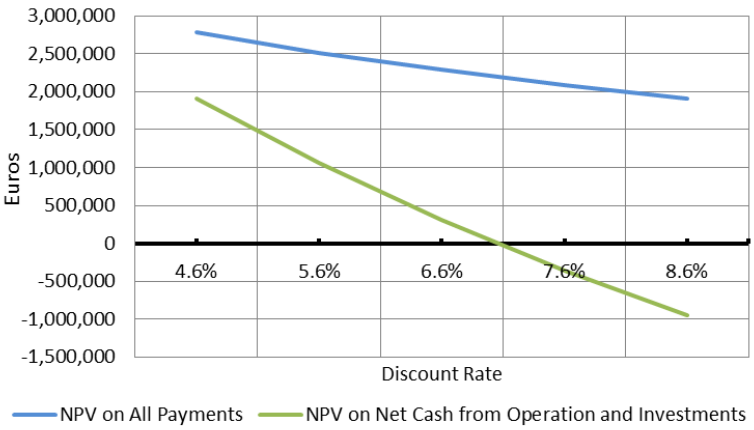


FIGURE 11: NPV SENSITIVITY TO DISCOUNT RATE

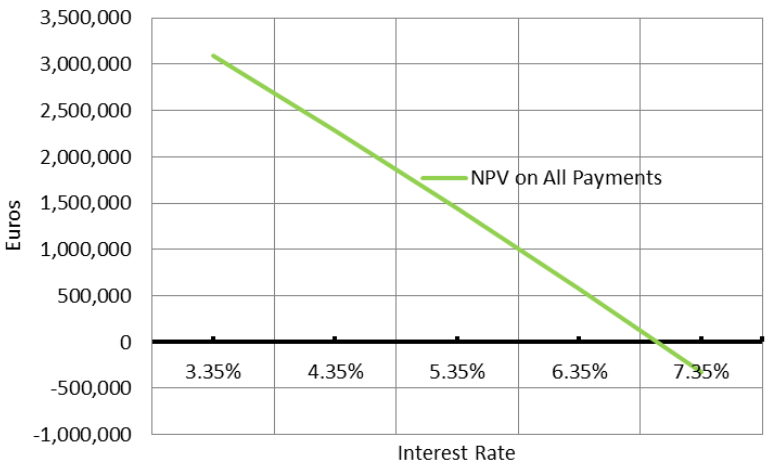


FIGURE 12: NPV SENSITIVITY TO INTEREST RATE ON LOAN

The NPV on all payments remains positive with an increase in the interest rate on money borrowed, up to approximately 6.8%, as shown in Figure 12. The initial interest rate of 4.35% was a quote from one particular financial institution, but is likely to vary depending on the terms of the actual lender chosen. The change in discount rate or interest rate has no effect on the operation of the system.

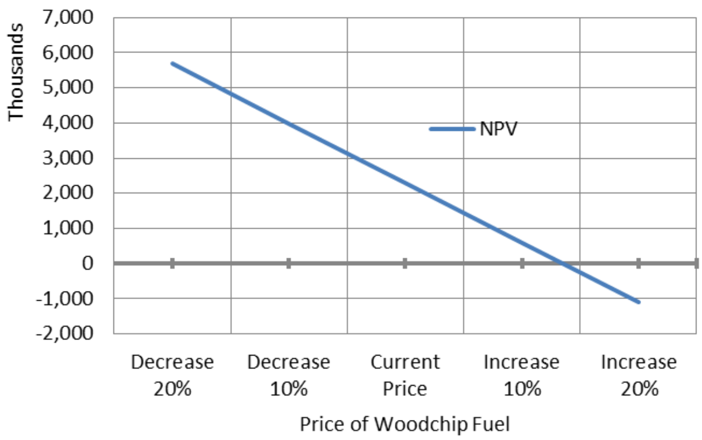


FIGURE 13: NPV SENSITIVITY TO PRICE OF WOODCHIP

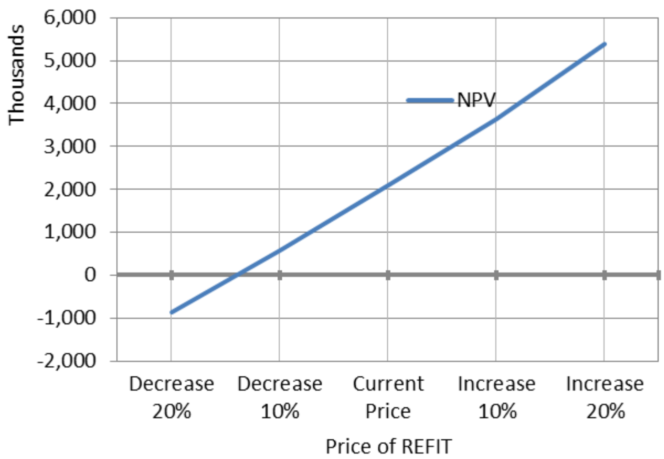


FIGURE 14: NPV SENSITIVITY TO PRICE OF REFIT

The price of woodchip per kg is varied up to +/- 20%, and the resultant NPVs are shown in Figure 13. The NPV becomes negative after approximately 12% increase in the price of woodchip. This increase/decrease is separate to inflation, which is applied over the project lifetime in all cases regardless of change in fuel prices. Throughout the range of prices analysed, the operational hours and fuel consumption of both CHP and boiler remain the same, meaning a change in price within the range shown does not affect the operation strategy, so the current REFIT price would still allow the CHP to produce heat cheaper than the gas boiler even if the price of woodchips grows by 20%.

Figure 14 shows the NPV becomes negative when the REFIT decreases by approximately 14%. The rate of change of NPV is lower than that when the price of woodchip is varied, meaning the system is more sensitive to a change in price of woodchip than REFIT. There is a slight change in the operational hours of the units with a change in REFIT; the CHP unit operates for slightly more hours, and boiler less hours, when the REFIT increases, but the amount of fuel consumed remains the same. Overall, even with a change +/- 20% to either woodchip or REFIT price, the percentage of RE fuel used and the emissions remain the same, so the environmental and renewable aspects are robust to a change in prices, and the financial feasibility is less robust.

The price of gas is already indexed to change over the project lifetime, separate to inflation, as described under the inputs. Therefore the results already include how the system reacts to an increase in gas prices, and it is shown in the previous Figure 4 how the operation and fuel consumption changes from year 1 to year 20.

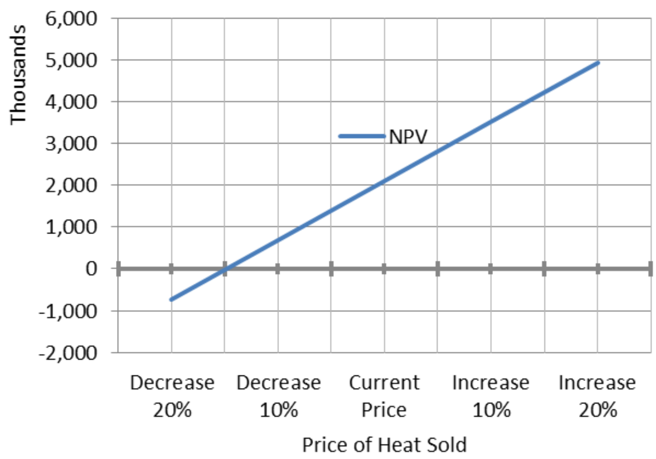


FIGURE 15: NPV SENSITIVITY TO PRICE OF HEAT SOLD

Price of heat sold can be set as low as 15% below the initial price set and still achieve a positive NPV. This means the price of heat sold could be lowered to approximately €33.1/MWh and achieve a NPV of zero. These prices would make subscribing to the system more appealing, especially if there are costs involved in changing the customer's current heating system to adapt to the temperatures from DH supply.

The weather data used, which is hourly ambient temperatures for 2010, was varied to data sets for other years, and the results show the maximum annual hourly demand does change, but not significantly, and the DH system still meets the demand with various annual weather conditions.

POTENTIAL OPPORTUNITIES

This section looks at some further economic and technical options which have not been fully analysed as they are not current options for this case study, but may become available in the future, could be applicable at another case study site, or are areas identified for further study. Scenario 4 is used as the base, and analysed to show how results would change if there were grants available for a percentage of the investment, tariffs for renewable heat production, if the system were to provide electricity onsite, and if there were a heat pump included in the system.

If a grant was available which would cover 25% of the total investment costs, the NPV would increase to €5,328,772 and the payback reduce to 11 years 3 months, which is nearly 4 years earlier than with a 100% loan. Even at only 25% of the investment, the grant would amount to over €2m, which is a high level of funding for one project.

The UK has launched a renewable heat incentive programme where a tariff is paid for every kWh of RES heat produced. The tariff proposed for Biomass CHP is 4.1p/kWh (Renewable Heat Incentive Ltd, 2014), and if a similar heat tariff were to be introduced in Ireland[7] and applied to scenario 4, the NPV increases greatly to €17.7m and the payback time reduces to only 5 years and 8 months. Interestingly, the same scenario, without the REFIT, and only a heat tariff applied, still results in an overall far better economic outcome, with an NPV of €10.5m and payback of 8 years. This then suggests that a tariff for renewable heat, which is around a third of the price of the tariff for renewable electricity from biomass CHP, is a far more attractive incentive for DH provided by CHP than the current REFIT.

[7] Taken as same price without currency exchange, €41/MWh

There is the possibility that the CHP could provide the municipal buildings with electricity, if they were deemed to meet the regulations and be seen as being part of the same premises[8]. The CHP electrical capacity could cover these buildings' electricity demand[9] when it is economically feasible to do so, and export excess to the grid. The system could supply this demand at the average price they currently pay per kWh, which is approximately €0.101/kWh[10] excl. taxes and charges, and sell the surplus through the spot market. The municipality will still need to pay the same standing charges for back-up connection to the grid for times when the CHP is not producing, which is why the price per kWh is used here, and not the delivered cost. In this case, the NPV of Scenario 4 decreases to €1.17m, and the payback time increases from 15 years to 17 years. If the same is applied to Scenario 7 (gas CHP & gas boiler), the NPV does improve greatly, up to €-2.9m, as the price currently paid by the municipality is much higher than the average SMP, but it is still not competitive with the biomass scenario. It is worth noting that, without the REFIT, scenario 7 becomes more economically attractive than Scenario 4 when using the electricity onsite and exporting the excess, at the current price paid for electricity.

Comparison of Scenarios when using Electricity Onsite					
	Exporting All Electricity		Exporting Excess Electricity		
Scenario	NPV €	Payback Years	NPV €	Payback Years	NPV Change %
Scenario 4	2,286,864	15	1,176,506	17	-49%
Scenario 7	-4,280,033	Not within Lifetime	-2,994,319	Not within Lifetime	30%

TABLE 3: COMPARISON OF BIOMASS VS GAS SCENARIO WHEN ELECTRICITY PRODUCTION USED ONSITE, EXCESS SOLD TO GRID

These outcomes are sensitive to the current price of electricity bought from the electricity supplier, and should be reanalysed if the price is to increase further. Other issues which need to be taken into account include the possibility of higher costs for electricity imports from the grid, as there are hours when it is not feasible for the CHP to produce electricity for the municipality buildings, and therefore they could be charged at a higher rate by their electricity supplier as the annual maximum demand will be much lower. There are also technical issues which arise when supplying the municipal buildings; the CHP unit has over 5 times more turn-ons and the boiler has double the turn-ons than when feeding the grid only, due to the fluctuations in the onsite electrical demand, which will increase the maintenance costs and decrease the lifetime of the machinery.

If the current price for commercial electricity rises to the same price per kWh as the REFIT, the gas fuelled Scenario 7 still retains a large negative NPV due to the small electrical demand of the municipal buildings. If regulations change and electricity could be provided to other buildings on the network, it is very likely that Scenario 7 would become more economical than Scenario 4, as the gas CHP has a higher electrical efficiency and much lower investment costs, but this would need to be investigated further taking into account changing technical aspects, and the additional costs of setting up the wire network and electrical back-up, which is outside the scope of this analysis.

Another technology option which could be included in the DH system is a large scale heat pump. There is much focus on including heat pumps in district heating systems in Denmark in order to make use of electricity at low prices, and storing heat, therefore helping to integrate more renewable wind resources onto the grid. The inclusion of such technology in a proposed DH system will depend on a source of heat input to the heat pump, i.e. ambient air temperature, water source or ground source, and will depend on

---

[8] This would depend on where the energy centre was located. Private wire network regulations can be found in appendix of the report at (SEAI, 2008).

[9] Electricity demand is linked to a time series for typical municipal office electrical distribution, and set to decrease by 33% to 2020.

[10] Taken from SEAI comparison of energy costs, electricity in Band ID >=2000<20,000MWh, and assuming approx. 10% of price quoted is standing charges and levies.

the heat temperature requirements of the system, as a heat pump will typically deliver lower temperatures than a boiler or CHP unit. In Ireland, the ambient air temperature in winter will be quite low and therefore the heat pumps coefficient of performance (COP) will also be low at times when heat demand is highest, and so a source of heat which has an element of seasonal storage, like the ground or a water source, will higher the efficiency. For this case study it is unknown if a heat source of this type is available. Also, current heating systems in existing buildings will require high temperature inputs, until such a time when large scale retrofits are conducted to lower the heating requirements. An analysis of Scenario 4 is run in order to show results of how an electric heat pump would affect the system using a variety of COPs, results are shown in Figure 16 below.

Scenario 4 with Electric Heat Pump 3MWth Output			
COP of HP	NPV	HP Production MWh	Boiler Production MWh
2.8	103,768	0	4809
2.9	105,337	0	4809
3	152,487	4,423	386
3.1	209,411	4,441	368
Heat Source @ 35°c			
3.6	453,422	4,530	279

FIGURE 16: HEAT PUMP ANALYSIS RESULTS

The net heat production cost of running the heat pump remains higher than that of the gas boiler until the COP of the heat pump reaches 3 and over. When the COP is above 3, the heat pump covers most of the heat demand above the base-load still covered by the biomass CHP, but the gas boiler is still needed for hours that the heat pump cannot cover, due to its heat capacity. A 3MWth heat pump is a typical size for a large scale application, and higher capacities are usually several units in parallel (Danish Energy Agency & Energinet.dk, 2012). Another heat pump could be included in place of the gas boiler, but the additional investment needed would turn the NPV negative. The DEA list heat pumps with a heat source at 35°C as having a COP of 3.6, and if this type of heat source was available at this case study site, the NPV increases to over double what it was when at a COP of 3.1, as can be seen in Figure 16, but even at this, the NPV still remains a lot lower than a system without a heat pump. Including heat pumps in an analysis of DH in Ireland may be too far ahead of the current knowledge of DH systems to be accepted, but could be an option for a research site or in the future if there is wide scale implementation of DH.

COSTS AND BENEFITS FROM A SOCIETAL PERSPECTIVE

The objective set out by the EU EE directive means the Irish Department of Communications, Energy and Natural Resources has to weigh up the costs and benefits of implementing widespread use of DH systems, and if there are excess benefits over costs, then Ireland needs to adopt measures in order to develop DH infrastructure, including policies specific to local and regional levels. The outcome of the analysis of the DH system for the south Dublin town centre has shown, from a socio-economic viewpoint, the following costs and benefits;

Costs

- Large investment capital needed with risk involved – innovative project
- Potential (short term) loss of business in the area with disturbances during construction
- Loss of revenues for natural gas producers (indirect cost)
- Loss of business for discrete heating system installers – (will still have business in areas of low heat density and potential to up-skill to install individual DH heat exchangers)
- Consumer investment needed – heat exchanger and meter
- Retrofits to buildings with existing heating systems may be needed

- Large scale deployment could increase the Public Service Obligation (PSO) levy due to financial feasibility dependent on REFIT
- Need to import knowledge of DH systems from other countries – no local experience
- Increased traffic caused by delivery of biomass

Benefits

- Higher security of supply (long term)
- Contributes to RE targets for both the grid and the heating sector
- Large decrease in fossil fuel use and therefore emissions
- Distributed power – less transmission losses
- More efficient system – less energy used
- Supports national biofuel production industry
- Increased domestic revenues
- Still profitable even if targets for energy efficiency in buildings is met
- Economically feasible under current policy – REFIT and priority dispatch
- Remains economically feasible under a large range of varying market conditions
- Increased local employment
- New skills developed – can be utilised further at other sites in Ireland
- Help to reduce current number of unemployed construction workers
- Many benefits to customers –
    - Low cost and price stability
    - Safer system – no carbon monoxide risks
    - No onsite water storage/boiler system needed – less space required
    - Very low noise from heat exchanger
    - Guaranteed heat supply on demand – no run-up times or immersions needed
    - Low maintenance requirements
    - No fuel deliveries
    - High pressure supply can negate the need for individual pumps
    - Choice of fuel sources– higher security of supply and competitiveness
    - Low local emissions – better health
    - Potential to decrease fuel poverty levels if extended to residential customers

As can be seen, there are more benefits identified than costs, with the majority of costs being short term, and majority of benefits being long term. This case study analysis concludes that there should be adequate initiatives put in place in order to assist the development of DH systems in areas with similar heat densities, so as to provide the benefits listed for heat consumers, and for the Irish economy as a whole.

DISCUSSION

The previous chapter has shown that DH is both technically feasible and cost-effective, and has more benefits for society than costs, and has therefore answered the initial research question. In order to answer the second research question, this chapter discusses the opportunities and barriers for DH in Ireland, and takes examples of lessons from other European countries, namely Denmark, which has successfully implemented DH at large scales. This chapter also then proposes changes in planning, regulations, initiatives and policies, based on the case study outcomes, literature review, email correspondence and DH workshop that could incentivise the use of DH in order to take advantage of the many benefits of DH already outlined in this report.

OPPORTUNITIES AND BARRIERS

This section outlines the opportunities and barriers for DH in Ireland. The outcomes of the case study have shown how an individual DH system affords many benefits to the local area and the economy, and this section seeks to find opportunities and barriers which could be possible if large scale DH was to be implemented throughout Ireland.

IRELAND'S HEAT DENSITY: BARRIER?

It has been cited many times that Ireland has not got the heat demands required for DH implementation. The case study analysed in the previous chapter is just one area, in one city in Ireland that has a high heat density, but there are many more like this and with even higher heat densities. The potential and feasibility for wide-scale use of DH, based on the outcomes of this analysis, are vast. Figure 17 below is from a recent study at Aalborg University, and this European heat atlas they have developed shows the theoretical heat density of Ireland. The Dublin region is shown to have high heat densities very similar to those of Copenhagen in Denmark. It can also be seen that Ireland and Denmark have similarly dispersed heat densities, while the UK has large areas of high heat density. DH meets over 60% of Danish heat demands with the heat densities shown, suggesting barriers to DH based on heat density should not be an issue for Ireland.

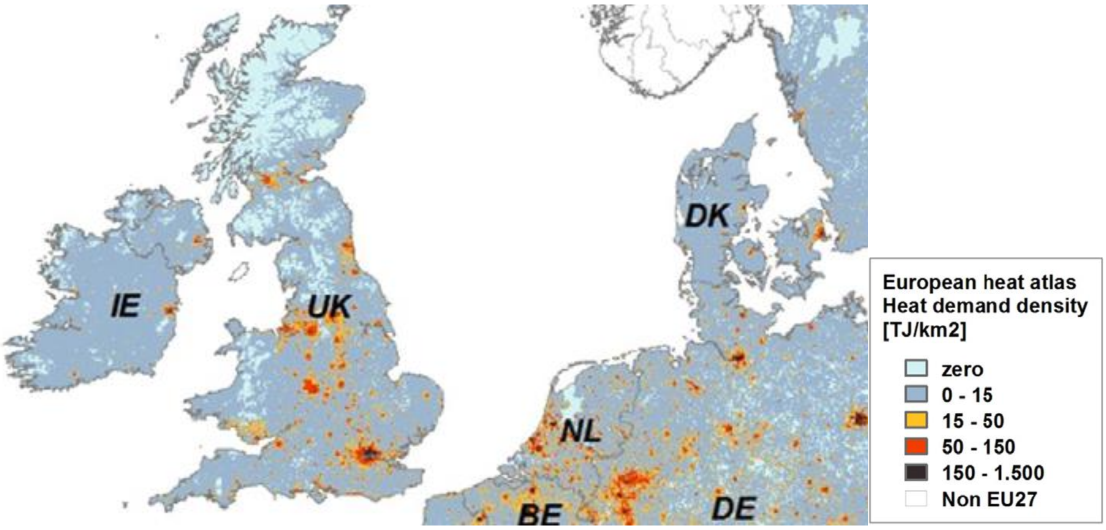
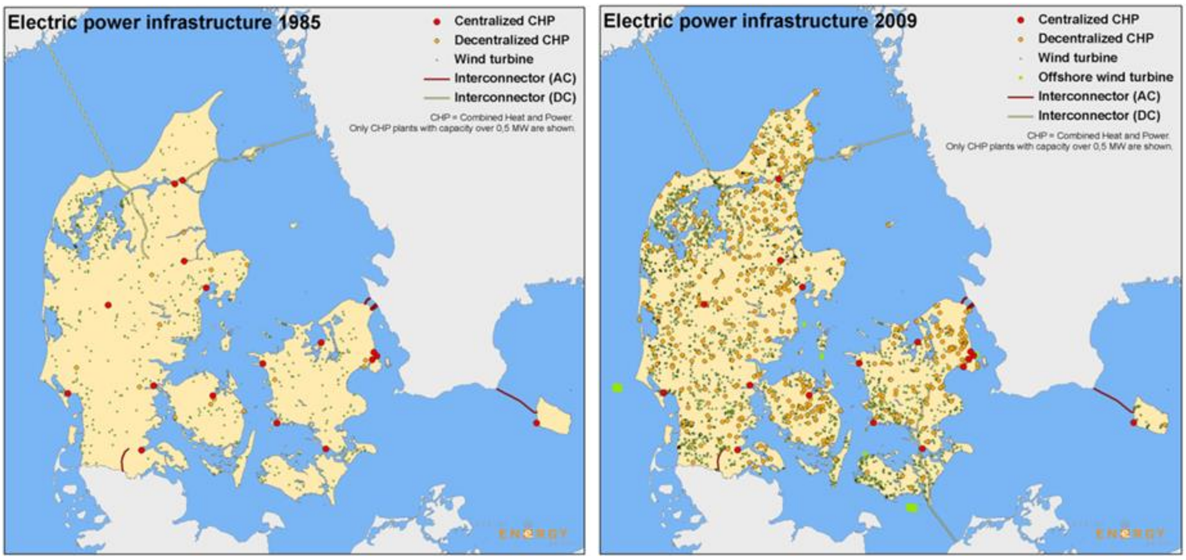


FIGURE 17: PART OF THE EUROPEAN HEAT ATLAS (CONNOLLY, ET AL., 2014)

OPPORTUNITIES: LESSONS FROM DENMARK

The value of using DH as an integral part of the whole island's energy system is overlooked in the Irish energy planning sector. DH is used in Denmark as a way to incorporate higher amounts of fluctuating renewable sources by using CHP and heat pumps with thermal storage on DH networks, and Denmark has a high level of energy storage in this form. The decentralised nature of these DH energy centres also decreases transmission losses in the system. Recognising the benefits, Denmark has legislation which obliges all CHP to connect and sell to the grid, for which they receive a monthly production independent premium (Andersen, 2014), but there are certain circumstances under which CHP can use net-metering and only sell surplus to the grid (Energinet.dk, 2013).The change from large centralised power stations to decentralised CHP in Demark between 1985 and 2009 is shown in the figure below, which shows the drastic change in the energy transmission system during this period.



The case study has shown that decreasing heating demands does not have a detrimental effect on the economics of the DH system when using CHP and thermal storage onsite. The future predicted reduction in heating demands and reduced delivery temperatures requirements also means more sources of low grade, low cost, heat can be considered and incorporated into the DH system. In Aalborg, Denmark, for example, there is a variety of waste heat sources fed into the DH grid, including waste heat from the local crematorium. Heat pumps and solar thermal heat can be utilised in low temperature DH systems and dramatically reduce the cost of heat production. There are also many areas of 'free' heat, where there are large amounts of heat being dumped (in Dublin examples are the Poolbeg power station and the Guinness' factory CHP plant in the city centre) beside areas where heat is required, which seems like an obvious solution to reducing fuel needed for heating. In Denmark, the share of renewables and waste feeding DH systems is continuing to increase, as seen in Figure 18 below, with more than half the systems fed by RE and waste in 2011. This integration of alternative sources in the heating sector of Denmark shows that DH is a clear way to enhance Ireland's security of supply and lower emissions.

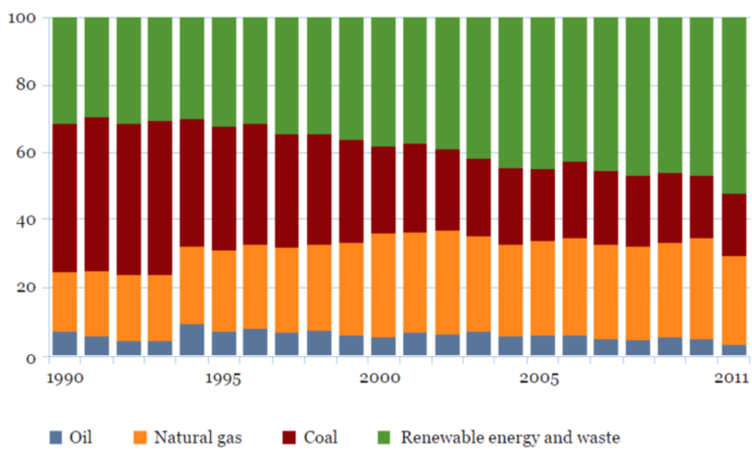


FIGURE 18: FUEL COMPOSITION FOR DH IN DENMARK, PERCENTAGE OF DISTRIBUTION 1990-2011 (DEA & DBDH, 2012)

European countries which have been highly successful at integrating large amounts of RES have had high shares of investments from communities and farmers, for example Germany's recent increase in RES has seen 53% of renewables now owned by citizens, municipalities and farmers in 2012 (Morris, 2013). Community and municipality involvement and investment by cooperatives have been a major contributor to the success of the renewable energy and DH sector in Denmark.

ACHIEVING IRELANDS RENEWABLE ENERGY POTENTIAL

Figure 19: Degree of Self-sufficiency in europe, 2011 shows the levels of self-sufficiency of countries around the world, and as can be seen, Ireland has the lowest degree of self-sufficiency in Europe, and is in the same percentage bracket as Japan. This puts Ireland in a precarious position in terms of security of supply. There is potential to learn from the Danish experience, and to increase the use of biofuels sourced within Ireland, in both the electricity and heating sectors through CHP/DH, and to help integrate more fluctuating wind resources, therefore increasing the level of self-sufficiency.

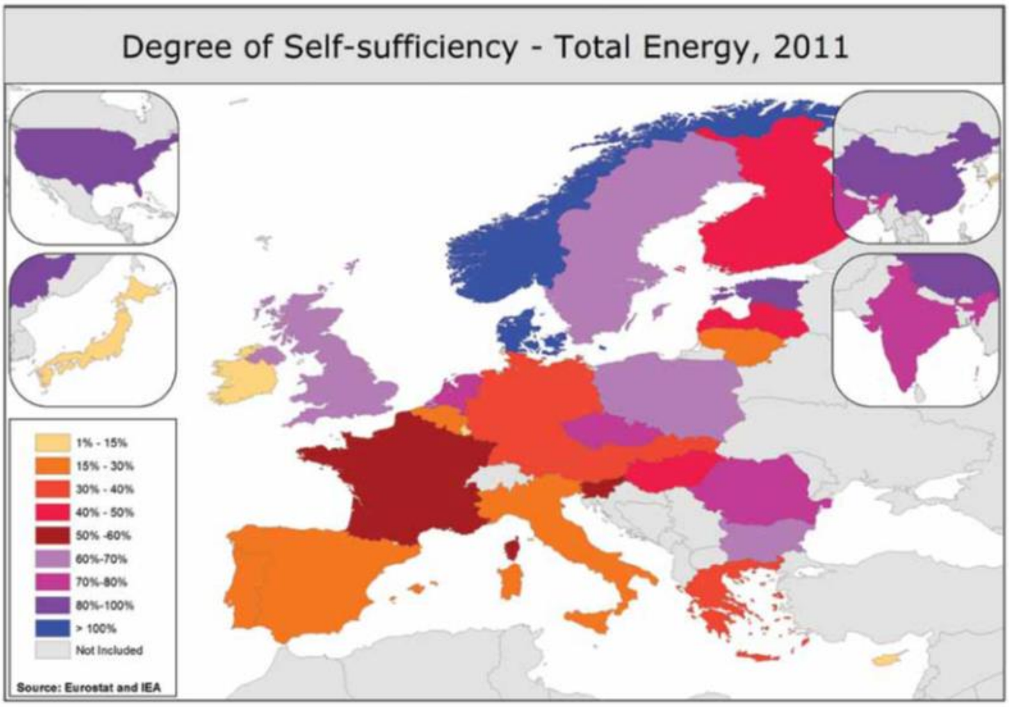


FIGURE 19: DEGREE OF SELF-SUFFICIENCY IN EUROPE, 2011 (DANISH ENERGY AGENCY, 2013)

Most DH systems currently in operation do not export electricity to the grid, and instead will find a way to use the electricity onsite, or use boilers only. The current policies encouraging grid connected HECHP and RE CHP units are thus not a sufficient incentive, as can also be seen by the rate of CHP installation discussed in the introduction. This then does not afford the benefits of thermal energy storage to the electricity grid. Implementation of large scale DH can have multiple effects, as well as allowing integration of more fluctuating RES onto the electricity grid it can help to meet CHP targets, help to achieve energy efficiency targets, reduce fossil fuel use in the heating sector and reduce heating costs for consumers.

The introduction of more renewable energy onto the grid with low marginal costs in the future means the average SMP is likely to decrease, and will mean lower incomes for CHP units. This said, the key benefit of supplying heat through DH is the increased flexibility in sources of heat production, and the lower SMP will encourage the connection of heat pumps, which will see higher revenues. The flexibility of DH to adapt to future changes in fuel prices and supply gives it an advantage over connecting to the gas grid, where there is only one choice of fuel. There is also opportunity to use the electricity produced from CHP to directly charge electric vehicles, as an alternative to selling to the spot market.

District heating is an opportunity to incorporate renewable energy into the domestic energy supply. There is currently less than 1% renewable energy used in the residential sector in Dublin City, and there are few opportunities to incorporate wind, hydro and solar power into built up urban centres. Using biofuels for DH and supplying DH in these areas is a feasible solution, and can allow urban communities to be involved in the green energy economy, which is currently seen as an opportunity only for those with land in rural areas. Using biomass in cities brings up the issue of increased transport disruption due to the increase in large goods vehicles for shipping the biomass to the DH energy centre. Other countries have gotten over this by placing the energy centres on the edge of city boundaries, in areas where there is efficient road infrastructure, or using waterways as an alternative transport route. These options are often not available to individual DH systems as they are restricted to constructing energy centres in areas onsite, which reinforces the need for integrated large scale planning of regional DH systems. There is also geothermal and solar thermal energy, which are often not considered in Irish DH studies, but can play a considerable role in DH systems in the future.

Ireland has potential to produce significant amounts of biomass to be used in all three energy consuming sectors of transport, electricity and heat. Production of energy crops is still relatively undeveloped and is an area of opportunity for farmers to exploit with increasing focus on use of biofuels in the national energy framework. 33% of Irish roundwood harvested in 2011 was used in energy generation sector (Coford, 2012). A study of the potential socio-economic benefits of bioenergy in Ireland has shown that an investment of €1.5 billion in the biofuel sector is needed in order to meet national renewable energy targets, but would result in increased employment and 7.5% reduced costs of energy imports (DKM & RPS, 2012). It is unlikely this amount of investment will come from public funding in the near future, which suggests the biofuel sector in Ireland will struggle to meet energy target requirements for all three sectors, and there could be potential problems with attaining biofuels for DH systems in the future unless production is increased.

NEW OPPORTUNITIES

There is currently a housing shortage in Dublin, which has seen the prices for dwellings increase by 23% between 2013 and 2014 (Burke-Kennedy, 2014). The low levels of construction that have been experienced since the economic recession are set to rise again, with the government recently launching a 'Construction 2020' strategy to increase building industry activity and overcome current housing shortages in the city (O'Halloran, 2014). This is a timely opportunity to ensure that the feasibility of implementing DH systems in these new housing developments is investigated at the planning stages, or include DH pipelines at the construction stage to enable future connection to planned DH networks. This is where regional energy planning guidelines are needed in order to coordinate new energy projects, so that integrated energy systems can be investigated as opposed to focussing on individual solutions for each new building, and costs can be minimised by implementing projects concurrently, e.g. DH pipelines alongside new road access, tram extensions, gas/water mains etc.

There is opportunity now to take advantage of the works which will be carried out by the newly formed Irish Water, who are the body which look after the provision of drinking water and sewage systems in Ireland. Setting up the infrastructure needed for DH networks could be implemented concurrently to the upgrade of the current water system.

DH can also help to meets targets of reducing waste disposal to landfill, by incorporating energy recovery facilities to provide heat to the network. Recovery facilities are outlined in waste management policy in Ireland as a way to reduce landfill and decrease our dependency on fossil fuels (Irish Department of Environment, 2012). Local authorities have responsibility for waste management planning, and can take this opportunity to link the needs of landfill reduction with the need for alternative and inexpensive fuel sources for the heating sector.

The current implementation of DH in Ireland focuses on the particular needs of the individual site, and not the energy system as a whole, as there is no obligatory strategic energy planning at a local and regional level. Energy concerns in municipalities have often concentrated on reducing their own energy use in public buildings, particularly due to the national targets which enforce 33% reductions in the public sector. There have been energy agencies established for most counties in Ireland, with some having recently carried out energy plans on a regional level, like the Limerick Clare Energy Plan, the South Tipperary Renewable Energy Strategy, or Sustainable Energy Action Plans (SEAP) carried out by Codema and South Dublin County Council (Connolly, et al., 2012) (STCC & TEA, 2014) (SDCC, 2013) (Codema, 2010). These plans are still separate entities to the regional planning guidelines.

Developing municipal level renewable energy strategies has been recognised by the SEAI, who produced a guide for local authority planners to implement '*Local Authority Renewable Energy Strategies*' (LARES) so that a bottom up approach can contribute to the national level RE targets. This guide includes some information on considering DH in a renewable energy strategy, citing that DH is most suitable in areas of high energy density and new developments (SEAI, 2013). This guide is concerned with RES for DH, and does not mention potential for using waste heat or waste-to-energy plants. The guide should help to see more consideration of DH in regional planning, but as it is focussed on helping to implement NREAP strategies, within which there is no consideration of DH, and thus there is less focus on DH and in particular its benefits concerning energy efficiency and its ability to use multiple heat sources. There is opportunity, with the already established energy agencies, many of which now have experience in energy planning, to look at introducing requirements for regional energy plans, which take all energy consumption and potential energy sources into account. This would require expansion of the current energy agency resources.

The latest large scale national energy planning initiatives in Ireland have been met with many protests from communities and local groups, and have created a poor perception of energy projects. There is now a strong anti-wind turbine and anti-pylon contingent in Ireland, due to a lack of consultation and community involvement in national energy plans. The TSO's plans to extend the network of high voltage overhead power lines and increasing the number of pylons seen across the landscape caused major protests, debate, and questions to be raised as to why the cables could not be installed underground. This backlash came about due to the fact that the communities affected were not consulted about the plans for the grid support extensions, and they were not informed of the alternatives that were available. This echoes the values of 'choice awareness' discussed in the theory chapter; all alternatives were not evaluated, and the public were told there was no other choice. There were plans to build 2,300 wind turbines with a capacity of 5000MW in the mid-lands of Ireland, which would export all of their power directly to the UK (McGreevy, 2014). There were two large multi-national companies involved who would profit from the project, with no involvement of local cooperatives or compensation offered to those in the areas affected. In April this year (2014), thousands of anti-wind and anti-pylon protesters marched in Dublin, and the main reasons cited for the protest were the government's failure to listen and engage with community concerns, and health risks (Griffin, 2014). These events may have created a poor public perception of the government's intentions in the energy sector and of the renewable energy sector in general. If any major change to the energy infrastructure is planned again, like those which would come about with large scale implementation of DH, then the same mistakes cannot afford to happen again.

Large scale implementation of DH is more sensitive to changes in the current institutional structures than technical system changes. The DH solution *is* the change to the current technical solution, and has the flexibility to incorporate many technical solutions should one or other become more beneficial, and can potentially be a completely separate entity to current electricity system set up, although grid connection can afford higher overall system efficiencies and economic benefits. Institutional changes, like rising fuel costs, reduced FITs, or increased incentives for individual heating solutions can have a large impact on future feasibility, therefore there are risks which come with institutional instability.

In summary, the main opportunities and barriers are;

- There are areas of large heat demand
- There is a need to integrate RE into the urban environment
- DH can help to meet targets of CHP, energy efficiency, RES in heat sector and in electricity sector.
- Established energy agencies can be a means to creating coordinated regional energy plans
- Future demand reductions will mean more sources of heat can be considered
- Waste to energy plants using waste as fuel can reduce landfill and provide heat and power
- Opportunities to use the heat being currently being dumped to atmosphere
- Need to increase levels of self-sufficiency
- Biofuel potential, but future production level is not certain
- DH systems have flexibility to integrate many sources of heat
- Potential recovery of construction sector
- Sensitive to institutional changes
- DH is not considered as an integral part of the overall energy system
- No regional energy planning
- Current poor public perception of government energy plans

POLICY AND PUBLIC REGULATION

The case study in this report has shown that DH can be feasible under short term, market based economics, and the results revealed there were more benefits than costs from a societal perspective. The analysis of opportunities and barriers has shown that there are many opportunities for Ireland with large scale deployment of DH, experience from other countries that can be learned from, and barriers that need to be overcome in order to take full advantage of DH.

These outcomes show that there is a need for policies and regulations to be put in place in order to encourage implementation of DH and develop heat markets on a regional level, and this section seeks to answer the second research question by outlining proposals for changes needed at both national and local levels in order to make this happen. These proposals are the result of the study carried out in this research paper, using the analytical tools outlined in the methodology chapter.

The current method of increasing efficiency and the renewable share of total heating demands in Ireland is greatly influenced by the path of least resistance, which is to look to end of pipe solutions which cause the least disruption and have short term costs, but which are not necessarily the most socio-economic alternative available, and do not prioritise long term benefits. Ireland's heat market is stagnant, much like the transport sector, and has not developed new and more sustainable solutions in the same way that new solutions have developed in the electricity sector.

In order to achieve long term societal benefits of DH, there needs to be a completely new path established, which is not going to be achieved if reliant on the current neo-classical 'free market' ideal to do so. The traditional method of examining economic feasibility based on short term economics is not applicable for DH systems, as the networks have lifetimes up to 40 years and beyond. Although the case study has shown that DH is technically feasible, and economically feasible under current market based economics, it is still not appealing enough to attract private investment. Developing the heat market can be done in several ways, which include; creating attractive short term market conditions surrounding DH to encourage private investment in order that the optimal long term solution for society is achieved, or invest public funds so that society can have direct long term benefits from a publicly controlled heating infrastructure, or a combination of both private and public investment.

There are many issues regarding the progress of DH to be addressed in this chapter, with the prevailing issues concerning planning and financing. The sections regarding planning, consultation, regulations and municipal involvement are seen to be long term institutional changes, whereas the financial supports suggested are short term measures to influence market conditions.

COORDINATED ENERGY PLANNING ON A REGIONAL LEVEL

The first and foremost issue which needs to change in order to develop DH in Ireland is the lack of a holistic approach to integrated energy planning on a local and regional level. Current energy planning sits at a national level, and assumes the right solutions for the right areas will filter down from top to bottom, and those projects which are implemented at the bottom then only consider their own needs and interests on an individual basis. In this way energy planning in the heating sector is incohesive, and there is a need for coordinated planning which includes provisions for sustainable heating above an individual case level and below the national planning level. Current regional planning guidelines do not consider energy supplies; they do not consider how actions regarding energy supply in new developments or upgrades to already established developments should be considered in a synchronised manner so that heat demands can be matched with heat rejections, networks can be shared, investments can be distributed, waste can be reduced, disruptions can be minimised, and the area can benefit as a whole. It is very unlikely that large scale DH networks will develop until there is more integrated planning of individual heating needs.

The first step in achieving this is to create a heat map for all regions in Ireland, where all heat demands and wasted heat is accounted for, and when this is established, areas which have high potential for DH can be identified. An energy planning department in each municipality could carry out such studies of their own region, and work with other planning departments in a harmonised effort. The case study in this report showed how with information for four buildings in one area, it was shown that DH was a feasible option. If the information was available for every building, and the local authorities were equipped with the skills to carry out these studies, a roadmap for DH can be established. Establishing regional scale DH planning also allows the strategic placing of energy production centres in areas which will cause the least disruption to the already established infrastructure and norms. This can then help to avoid protests from local residents, increased traffic congestion, disruption to businesses etc.

PUBLIC CONSULTATION & COOPERATIVE INVOLVEMENT

What has been the downfall of late in Irish national energy planning, particularly that in the implementation of wind power, has been the lack of community awareness and involvement in energy projects from the beginning. The regional energy plans suggested in this chapter should be open for consultation to the public before any developments are allowed to continue, and provision for cooperatives to invest into local energy projects should be a priority. If more consumers have a stake in the development of DH, and are educated of the many benefits of DH, it is likely to meet fewer barriers.

Ideal candidates for cooperative investments in DH schemes are biomass farmers. These farmers have a vested interest in increased use of biofuels, and will be doubly rewarded if investing in bio-fuelled DH systems. This arrangement can also help to secure low guaranteed prices for biomass fuel.

REGULATORY SUPPORT

There are currently no guidelines available for implementing DH systems, which is an issue as there is no experience or exemplar projects to look to as examples, and therefore there is always an element of ambiguity in DH feasibility studies, especially regarding financial aspects. There are no contractual regulations or operational requirements for the protection of both consumers and suppliers. There is a lack of clarity regarding VAT on fuel imported to fuel HECHP and boilers in DH systems. The case study in this report shows that if fuel costs are increased by the 13.5% rate of VAT, and is not recouped, directly or indirectly, by collecting the tax from consumer bills, then the system cannot provide heat at a price competitive with current gas fuelled individual heating system solutions. The SEAI are currently working to clarify the issue regarding VAT on fuel for CHP units and biomass fuelled projects, but is not currently working on any specific for DH. Inspiration from Denmark can be taken in this regard, where municipalities directly receive the VAT from consumer bills to counter the VAT costs on fuel imported, and report these transactions to the tax office. Whatever the decision, the situation for DH specific projects needs to be clarified. In order to fulfil EU obligations and encourage the use of DH, the Department of Energy and the Commission for Energy Regulation need to establish regulations directly aimed at the development of local heat markets to create security and lower perceived risks.

MUNICIPALITY INVOLVEMENT

Municipalities are an ideal owner-operator of DH networks as they can operate the company as a not-for-profit company, passing on savings directly to consumers, look at the investment as a long term benefit for the community and afford longer paybacks, and potentially meet with fewer barriers in planning and establishing consumer connections. The services provided by local authorities directly to the community they serve have almost diminished entirely in recent years. The level of control and responsibility afforded to municipalities is low, especially in comparison to those in other European countries, where there has been a 're-municipalisation' of energy services in many cases. DH planning is suited to a regional level public body, and as discussed previously in this chapter, there needs to be coherence between national level planning and what is being implemented at a local level. Giving the municipalities responsibility for their own region's energy use and emissions, and specifying targets which are specific to the characteristics of that location i.e. high targets for DH in high heat density areas, will see more actions carried out with a bottom-up approach to meeting national targets. Currently municipalities are only concerned with meeting obligations of energy reduction in their own public buildings, and would need available finance if investing in large scale energy projects.

There are restricted budgets for any public investments in the current economic climate in Ireland and so it is hard to see how municipalities would find funding. Alternative and innovative ways of financing may need to be established, like how the Dublin City Council implemented the Dublin Bike scheme; the council traded advertising space to a private company who in exchange funded the scheme, which has been a very successful arrangement. The municipalities may need to look at other assets which could be used in similar arrangements. The availability of interest free loans for local authority energy projects, much like the loans available for the public sector from Salix Finance in the UK (Salix Finance, n.d.), would mean that projects which require large upfront investment can be considered by municipalities. The case study has also shown how DH projects can be economically feasible, and would pay back in a relatively short period. Another option is for the municipality to invest in the network only, and charge a DH company for use of the network, much like a distribution system operator on the electrical grid. This way an ESCO can invest in the energy centre only and not worry about recouping costs of investment-heavy network piping. To ensure the viability of such a project, the municipality would need to gauge the level of interest from the private sector and quantify the areas with the highest potential for DH before developing a network, increasing the chances of success and reducing risk for investors. The suggested regulation surrounding a potential heat market should also account for this type of contractual arrangement.

The local authorities also have the ability to make arrangements that could secure the connection of businesses and households to the network. They could offer reductions on commercial property rates for businesses, if consumers agree to connect. This could be a once off tax break for one year upon connection, or a yearly reduction to ensure continuous connection. For residential property owners, a portion of the recently established local property tax (LPT) could be used to invest in municipal energy services. Currently the tax collected is used as general public revenue, however when the economy starts to stabilise, funds from each municipality could be ring fenced for municipal energy services to reduce energy use in each constituency.

FINANCIAL SUPPORTS

Financial supports are short term measures which can be introduced in order to allow DH to gain a foothold in the Irish energy market and break through the current barriers, much like the supports that have been put in place for RES in the electricity sector. There are currently no direct financial incentives or supports for DH, and investments and financial security was at the forefront of the stakeholder discussion during the DH workshop in Dublin.

The current REFIT is the closest indirect financial incentive, but is in place to encourage renewable electricity rather than renewable heat production. Most DH projects which have been and are in the process of being implemented do not sell electricity back to the grid, so this support is not appropriate for the current pattern of DH installation. Inspiration could be taken from the UK's Renewable Heat Incentive scheme, which pays a tariff for every kWh of heat produced. The case study has shown how a tariff for heat per MWh, which is much lower than that of the current REFIT for CHP, made a large improvement to the short term business economics. From this perspective, it needs to be clear where DH stands in terms of the overall energy system; if it is seen to be an integral support for the electrical grid through energy storage then connecting to the grid should be incentivised to a higher degree, or if the role of DH is simply to integrate more RE and waste heat into the heat sector then a tariff for heat produced is the solution, but overall, the ideal solution would be a balance of both.

The current grants for domestic high efficiency oil and gas boilers encourage and support the use of fossil fuels in the residential sector for the next 20 years. This needs to cease and change to supporting more efficient and sustainable means of heating. When areas are identified for the implementation of DH, buildings in these areas need to be allocated grants for DH heat exchangers and meters, and supports for heat pumps or solar thermal units, for which there are currently no grants or supports, in other areas of low heat density.

In the electricity sector, there is a Public Service Obligation (PSO) levy paid by electricity consumers in order to fund the use of indigenous fuel sources to increase security of supply, which refers to peat consumption, and fund the REFIT scheme and capacity payments. There is no equivalent to this for the heating sector to support the use of indigenous biofuels and increase security of supply in a sector which is 83% reliant on imported fuels to meet demand. The carbon tax, which is put on the use of fossil fuels in the non-ETS sector, is not ring-fenced to be used to support sustainable or indigenous heating fuels, and instead goes into the general public sector fund, and is seen to be enough to discourage the use of fossil fuels in the heating sector. This tax needs to be reinvested back into the heating sector in order to fund the financial supports needed for the development of regional heat markets and DH systems based on biofuels.

From consultation at the DH workshop held recently in Dublin, there were stakeholders who felt the REFIT was not secure enough to use in economic feasibility studies, and would not risk investing in projects which were reliant on the tariff. There are also a very low number of CHP units currently being installed, and an even lower number are bio-fuelled. This may be due to the fact many other financial incentives were cancelled in recent years, but the REFIT for wind power in particular has been in place for quite some time now and many investors have taken advantage of these guaranteed prices. The current FIT for bio-fuelled CHP is approximately double the average SMP, so the price itself is obviously not the issue. There needs to be further investigation and stakeholder engagement in order to fully understand the lack of interest in CHP investments.

SUMMARY

In summation, the following table outlines the points addressed in this chapter, under the headings of 'current situation' and the 'ideal situation' for DH, and 'what needs to change' in order to create the ideal situation and allow DH development.

Current Situation for DH	Ideal Situation for DH	What needs to change
No regional energy planning	Regional energy planning which sets out a roadmap for DH implementation	Establish a methodology for integrating energy planning into regional planning, set up local energy planning depts.
Uncoordinated implementation of planned infrastructural projects	DH network implemented at same time as other scheduled works to cut costs/disruption	Synchronised scheduling of works based on regional plans, communication between depts.
Lack of knowledge and experience of DH	Municipalities have knowledge and experience of running successful DH projects	Import knowledge from experience in EU in exemplar projects, educate & train locally
Low uptake of CHP under current incentives	Incentives which encourage use of large scale HECHP	Investigation into low uptake of HECHP
Lack of financial guarantees	Low risk investments in DH projects	State guarantees on investments
Grants for domestic oil & gas boilers	Grants for consumer heat exchangers/meters	Cease grants for oil/gas boilers in areas allocated for DH, grants instead for heat exchangers/meters
No mapping of heat demands/surplus	All areas of high heat density identified and allocated for DH	Nationwide mapping of heating requirements and heat surplus, based on actual data recorded
No incentives to connect to a local DH network	All nearby consumers will connect to the DH network	Incentives to join the network; e.g. reduced property tax
Lack of public consultation on large scale energy projects	All consumers are educated and supportive of DH	Communication with public from beginning of planning process
Lack of cooperative investment in energy projects	Local communities benefit directly from investing in DH	Encourage and support energy cooperatives, percentage of investment set for co-ops
Focus on short term business economics	Focus on long term socio-economic benefits of DH	Ensure short term economics are attractive in order to achieve long term benefits
No financial incentives for using RES/surplus heat	Incentives to produce heat from RES or use surplus heat in DH	A tariff for RES heat per MWh, like that of the REFIT scheme, and price for selling surplus heat
Low levels of public capitol available	Local Authorities can invest in DH network	Interest free loans available to Local Authorities for energy projects
No regulation for a heat market	Regulation which protects both consumers and suppliers	DCENR & CER develop regulations for local heat markets

FIGURE 20: SUMMARY OF POLICY AND PUBLIC REGULATION FOR DH

CONCLUSION

This research paper sought to answer the research questions;

Do socio-economic benefits outweigh costs when implementing large scale District Heating on a local level in Ireland?

And if so, what policies need to be adopted in order to encourage the use of district heating systems, preferably fuelled by renewable sources and surplus heat, and development of heat markets at a local and regional level in Ireland, in order to meet the requirements of the EU Energy Efficiency Directive?

The first research question has been answered through a techno-economic case study analysis of a proposed large scale DH system, using energy system modelling software, and was found to be technically and economically feasible under short term market based economics. The cost-benefit analysis which followed concluded there were more benefits than costs from a societal perspective, and the majority of benefits were long term whilst costs were short term.

With this outcome, the second research question has been answered through an analysis of the opportunities and barriers of using large scale DH systems throughout Ireland and suggested policy and regulation reform in order to develop DH and regional heat markets, based on the case study analysis, literature review and stakeholder discussions. The main regulatory measures identified are the need for coordinated regional energy planning and financial supports and incentives specific for the heating sector.

The key findings of this research paper are;

- DH is technically and economically feasible under current short-term market based conditions
- There are more benefits than costs for society when implementing large scale DH systems at a local level, with benefits being long term and costs being short term
- The main barrier to the progress of DH is the lack of regional level energy planning
- A roadmap for the heating sector needs to be developed
- Regulation for a heat market needs to be established to protect from risks
- There is need for short term financial supports specifically for heat production to influence market based investments

BIBLIOGRAPHY

Andersen, A., 2014. *Email Correspondence: Legislation regarding CHP grid connection in Denmark, 26th May 2014.* s.l.:Anders Andersen, Department of Development and Planning, Aalborg University.

Bradley, M., 2014. *Email Correspondance with Malachy Bradley, Regional Planning Guidelines Officer: 'Enquiry into District Heating planning guidelines'* [Interview] (7 March 2014).

Burke-Kennedy, E., 2014. Dublin property prices now rising by €5,000 a month, survey finds. *The Irish Times*, 1 April.

Central Statistics Office, 2012. *Census 2011 SAPMAP Viewer.* [Online] Available at: http://census.cso.ie/sapmap/ [Accessed October 2013].

CER, 2009. *Treatment of Small, Renewable and Low Carbon Generators outside the Group Processing Approach,* Dublin: CER.

CER, 2011. *CER Factsheet on the Single Electricity Market,* s.l.: CER.

City of Copenhagen & Ramboll, 2012. *Copenhagen: Solutions for Sustainable Cities,* Copenhagen: City of Copenhagen.

City of Copenhagen, 2012. *Copenhagener's Energy Consumption.* [Online] Available at: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/ClimateAndEnvironment/CopenhagensGreenAccounts/EnergyAndCO2/Consumption.aspx [Accessed 7 May 2014].

Codema, 2010. *Dublin City Sustainable Energy Action Plan 2010-2020,* Dublin: Codema.

Codema, 2012. *Dublin District Heating System Market Assessment,* Dublin: Codema.

Codema, 2014. *Dublin District Heating Workshop - Emerge Project, 21st May 2014.* Dublin, Codema.

Coford, 2012. *Woodflow and forest-based biomass energy use on the island of Ireland 2011,* Dublin: Coford.

Connolly, D., 2014. *Email Correspondance to questions posed relating to DH in Denmark* [Interview] (1 May 2014).

Connolly, D. et al., 2014. Heat Roadmap Europe: Combining District Heating with Heat Savings to Decarbonise the EU Energy System. *Energy Policy,* Volume 65, pp. 475-489.

Connolly, D. et al., 2012. *Limerick Clare Energy Plan: Climate Change Strategy,* Limerick: Limerick Clare Energy Agency.

Connolly, D. et al., 2014. *Heat Roadmap Europe; Inputs for Technical Modelling and Policy Recommendations,* Aalborg: Aalborg University.

COWI, 2012. *Conversion of Heating Installations into District Heating (Draft Oct 2012),* Dublin: RPS/Codema.

Curtis, J., di Cosmo, V. & Deane, P., 2014. *Climate Policy, Interconnection and Carbon Leakage: The Effect of Unilateral UK Policy on Electricity and GHG Emissions in Ireland,* Dublin: ESRI.

Danish Energy Agency & Energinet.dk, 2012. *Technology Data for Energy Plants,* Copenhagen: Danish Energy Agency.

Danish Energy Agency, 2013. *Energy in Denmark 2012,* Copenhagen: Danish Energy Agency.

DCENR, 2010. *National Renewable Energy Action Plan - Ireland,* Dublin: Department of Communications, Energy and Natural Resources.

DCENR, 2012. *Ireland's Second National Energy Efficiency Action Plan to 2020,* Dublin: Department of Communications, Energy and Natural Resources.

DCENR, 2013. *Consultation: Implementation of the Energy Efficiency Directive in Ireland,* Dublin: DCENR.

DCENR, 2014. *Green Paper on Energy Policy in Ireland,* Dublin: Department of Communications Energy and Natural Resources.

DCENR, 2014. *REFIT.* [Online] Available at: http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/REFIT.htm [Accessed 24 March 2014].

DEA & DBDH, 2012. *District Heating- Danish and Chinese Experience,* Frederiksberg: Danish Energy Agency and Danish Board of District Heating.

Dept. Public Expenditure and Reform, 2013. *Project Discount & Inflation Rates.* [Online] Available at: http://www.per.gov.ie/project-discount-inflation-rates/ [Accessed 7 April 2014].

DKM & RPS, 2012. *The Economic Benefits from the Development of BioEnergy in Ireladn to meet 2020 Targets,* Dublin: IRBEA.

DMI, 2013. *Decadal Mean Weather 2001-2010.* [Online] Available at: http://www.dmi.dk/en/vejr/arkiver/decadal-mean-weather/ [Accessed 24 March 2014].

Doyle, C., 2013. *Clean-Tech: Glen Dimplex CEO on the future smart grid and energy storage.* [Online] Available at: http://www.siliconrepublic.com/clean-tech/item/32746-oi2012 [Accessed 19 May 2014].

DPER, 2013. *Project Discount & Inflation Rates.* [Online] Available at: http://www.per.gov.ie/project-discount-inflation-rates/ [Accessed April 2014].

Dublin City Council, 2010. Ballymun Boiler House Shuts Down. *Ballymun Regeneration Newsletter Issue 90*, July/August.

Dyrelund, A., 2014. *Email Correspondance: Query regarding District Heating Tax in Denmark* [Interview] (2 May 2014).

Ecoheat4EU, 2011. *Recommendation Report for Ireland,* s.l.: Ecoheat4EU.

Eirgrid, 2010. *Gate 3 ITC Program 2010-2023 Firm Access Quantities,* Dublin: Eirgrid.

Eirgrid, 2013. *Gate 3.* [Online] Available at: http://www.eirgrid.com/gate3/ [Accessed 9 May 2014].

Eirgrid, 2013. *TSO Gate 3 Status Report: December 2013,* Dublin: Eirgrid.

EMD International, 2013. *How to Guide: Making automatic calculation of the operation strategy in energyPRO.* Aalborg: EMD International A/S.

EMD International, 2013. *Introduction.* [Online] Available at: http://www.emd.dk/energyPRO/Introduction/ [Accessed 21 May 2014].

EMD International, 2013. *Users Guide: energyPRO.* Aalborg: EMD International A/S.

Energinet.dk, 2013. *Nettoafregning.* [Online] Available at: https://www.energinet.dk/DA/El/Vindmoeller/Nettoafregning/Sider/Nettoafregning.aspx [Accessed 26 May 2014].

EPA, 2011. *Ireland's Greenhouse Gas Emissions Projections 2010-2020,* Dublin: EPA.

ESB, 2013. *Standard Prices for Generator Connections 2013,* s.l.: ESB Networks.

Euroheat & Power, 2013. *Heat Roadmap Europe 2050: Second Pre-study for the EU27,* Aalborg: Department of Development and Planning, Aalborg University.

European Commission, 2014. *2030 Framework for climate and energy policies.* [Online]
Available at: http://ec.europa.eu/clima/policies/2030/index_en.htm [Accessed 24 March 2014].

Fedorkiw, N., n.d. *Mainstream Renewable Power: Response to National Renewable Energy Action Plan,* Dublin : DCENR (Responses to National Renewable Energy Action Plan, via website).

Galliot, O., 2007. *Dublin Wate to Energy Project Brief of Evidence in relation to District Heating (part of Oral Hearing),* Dublin: Dublin Waste to Energy Project.

Gartland, D., 2014. *Dublin City Sustainable Energy Action Plan Monitoring and Progress Report,* Dublin: Codema.

German Energy Transition, 2013. *Energy by the People.* [Online] Available at: http://energytransition.de/2012/10/energy-by-the-people/ [Accessed 26 April 2014].

Gloystein, H., 2014. *Russia's South Stream Pipeline Splits EU Energy Policy.* [Online]
Available at: http://www.reuters.com/article/2014/04/17/us-ukraine-crisis-gas-southstream-analys-idUSBREA3G1KP20140417 [Accessed 21 April 2014].

Greater London Authority, 2013. *District Heating Manual for London,* London: Greater London Authority.

Griffin, D., 2014. *Thousands protest against pylons and wind turbines.* [Online]
Available at: http://www.irishtimes.com/news/environment/thousands-protest-against-pylons-and-wind-turbines-1.1763015 [Accessed 23 May 2014].

Hawkey, D. J., 2012. District Heating in the UK: A Technological Innovation Systems Analysis. *Environmental Innovation and Societal Transitions,* Volume 5, pp. 19-32.

Healy, G., 2013. *Issues In Accessing Enormous Renewable Resource In Ireland: Prepared for IRENEC 2013,* Galway: Ierne Limited.

Heat Coalition, 2014. *Press Release: 2030 climate and energy framework: the Parliament calls for heat strategy.* Brussels: Heat Coalition.

Hvelplund, F. & Lund, H., 1998. *Feasibility Studies and Public Regulation in a Market Economy,* Aalborg: Aalborg University.

IEA, 2007. *The International CHP/DHC Collaborative; Advancing Near-Term Low Carbon Technologies, CHP/DHC Country Scorecard: Denmark,* Paris, France: IEA.

IEA, 2013. *World Energy Outlook 2013,* s.l.: IEA.

IPCC, 2007. *Projections of Future Changes in Climate.* [Online] Available at: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html [Accessed 10 April 2014].

Irish Department of Environment, 2012. *A Resource Opportunity: Waste Management Policy in Ireland,* Dublin: Department of Environment, Community and Local Government.

Irish Revenue Commission, 2013. *Guide to Natural Gas Carbon Tax,* Dublin: Irish Revenue Commission.

IWEA, 2014. *Connecting to the Network.* [Online] Available at: http://www.iwea.com/connectingtothenetwork [Accessed 28 May 2014].

Kavanagh, R., Waldron, F., Ruane, B. & Oberman, R., 2012. *Education, Climate Change and Climate Justice Irish Perspectives,* s.l.: AERA Conference.

Keegan, O., 2014. Poolbeg Incinerator Remains a Burning Issue. *Council Review Issue 43*, pp. 33-35.

Lang, M., 2013. *Hamburg Votes in Favour of Remunicipalisation of Electricity, Gas and District Heating Distribution Grids.* [Online] Available at: http://www.germanenergyblog.de/?p=14400 [Accessed 26 April 2014].

Law, J., 1987. *Technology and Heterogeneous Engineering: The Case of Portuguese Expansion.* Cambridge, Massachusetts: MIT Press.

Lund, H., 2010. *Renewable Energy Systems: The Choice and Modelling of 100% Renewable Solutions.* s.l.:Elsevier.

Lund, H. & Clark, W. W., 2000. *Management of fluctuations in Wind Power and CHP Comparing Two Possible Danish Strategies,* Aalborg: Aalborg University.

McGarrity, J., 2014. *Germany's carbon targets in doubt as emissions rise in 2013.* [Online] Available at: http://www.rtcc.org/2014/03/10/germanys-carbon-targets-in-doubt-as-emissions-rise-in-2013/ [Accessed 7 May 2014].

McGreevy, R., 2014. *Multi-billion wind energy deal unlikely to proceed as planned.* [Online] Available at: http://www.irishtimes.com/business/sectors/agribusiness-and-food/multi-billion-wind-energy-deal-unlikely-to-proceed-as-planned-1.1716726 [Accessed 23 May 2014].

Met Eireann, n.d. *Climate of Ireland.* [Online] Available at: http://www.met.ie/climate/climate-of-ireland.asp [Accessed 24 March 2014].

Michel, J., 2014. *Can Germany survive the Energiewende?.* [Online] Available at: http://www.energypost.eu/energiewende-doomed/ [Accessed 26 May 2014].

Morris, C., 2013. *German renewables still ground-roots movement.* [Online] Available at: http://energytransition.de/2013/05/german-renewables-still-ground-roots-movement/ [Accessed 26 May 2014].

Naharnet News, 2014. *Europes 'Greenest City' Tests Limits of Sustainable Living.* [Online] Available at: http://www.naharnet.com/stories/en/115500-europe-s-greenest-city-tests-limits-of-sustainable-living [Accessed 24 March 2014].

O'Halloran, B., 2014. Construction strategy to tackle Dublin housing squeeze and planning bottlenecks. *The Irish Times*, 15 May.

Pierson, P., 2002. Increasing Returns, Path Dependence, and the Study of Politics. *The American Political Science Review,* 49(2), pp. 251-267.

Poyry & Faber Maunsell, 2009. *The Potential and Costs of District Heating Networks,* Oxford: Poyry Energy.

Reck, H.-J., 2011. *Comeback der kommunalen Energieversorger Erster Saarländischer Energiegipfe,* Saarbrucken: VKU.

Renewable Heat Incentive Ltd, 2014. *Non-domestic scheme consultation.* [Online] Available at: http://www.rhincentive.co.uk/RHI/reviews/non-domestic/#1301 [Accessed 25 May 2014].

Revenue Commissioners, 2013. *Guidance Note on Solid Fuel Carbon Tax,* Dublin: Revenue Commissioners, Indirect Taxes Division.

RPS/COWI, 2007. *Dublin District Heating Project 2007 Feasibility Study,* Dublin: Dublin City Council.

RTE News, 2014. *Poolbeg Incinerator Project Cleared Over State Aid.* [Online]
Available at: http://www.rte.ie/news/2014/0507/615766-poolbeg-incinerator/ [Accessed 8 May 2014].

Ruester, S. et al., 2013. *From Distribution Networks to Smart Distribution Systems:Rethinking the Regulation of European Electricity DSOs,* s.l.: European University Institute.

Ryan, A., 2014. *Email response to query on Irish Public Sector Energy Blog "EnergyLink" 29/4/2014.* s.l.:Alan Ryan, Programme Manager, SEAI.

Salix Finance, n.d. *Loans.* [Online] Available at: http://salixfinance.co.uk/ [Accessed 26 May 2014].

SDCC, 2013. *South Dublin Sustainable Energy Action Plan,* Dublin: South Dublin County Council.

SEAI & WS Atkins Consultants, 2002. *Assessment of the Barrieres and Opportunities Facing the Deployment of District Heating in Ireland,* Dublin: SEI.

SEAI, 2008. *Connecting Renewable and CHP Electricity Generators to the Electricity Network,* Dublin: SEAI.

SEAI, 2012 (Update). *Combined Heat and Power in Ireland,* Dublin: SEAI EPSSU.

SEAI, 2013 (a). *Energy in Ireland 1990-2012,* Dublin: SEAI.

SEAI, 2013 (b). *Energy in the Residential Sector: 2013 Report,* Dublin: SEAI.

SEAI, 2013. *BER Research Tool User Information Guide: Version 1.0,* Dublin: SEAI.

SEAI, 2013. *Better Energy Home Scheme Statistics.* [Online] Available at:
http://www.seai.ie/Grants/Better_energy_homes/Better_Energy_Statistics/Website%20Stats.pdf
[Accessed December 2013].

SEAI, 2013. *Emission Factors.* [Online] Available at:
http://www.seai.ie/Publications/Statistics_Publications/Emission_Factors/ [Accessed 22 April 2014].

SEAI, 2013. *Methodology for Local Authority Renewable Energy Strategies,* Dublin: SEAI.

SEAI, 2014. *Fuel Cost Comparison.* [Online]
Available at: http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/
[Accessed March 2014].

SEAI, n.d. *Accelerated Capital Allowance.* [Online] Available at:
https://www.seai.ie/Your_Business/Accelerated_Capital_Allowance/ [Accessed 10 March 2014].

SEAI, n.d. *Renewable Heat Pumps in Healthcare Institutions,* s.l.: SEAI Renewable Energy Information Office.

SEI, 2008. *Energy End-Use in Ireland,* Dublin: SEI.

SEMO, 2014. *Market Data.* [Online] Available at:
http://www.semo.com/MarketData/Pages/default.aspx [Accessed March 2014].

Society for Cooperative Studies in Ireland, 2014. *Co-op Power: Seminar Proceedings Report 8th April 2014.* Dublin, The Society for Cooperative Studies in Ireland.

STCC & TEA, 2014. *South Tipperary Renewable Energy Strategy 2014,* Tipperary: South Tipperary County Council.

Sustainable Wood Energy, n.d. *District Heating.* [Online]
Available at: http://www.sustainablewoodenergy.co.uk/district-heating/#.U4WZ2SjyQR8 [Accessed 28 May 2014].

The Competition Authority, 2010. *Competition in the Electricity Sector,* Dublin: The Competition Authority.

The Regional Planning Guidelines Office, 2010. *Regional Planning Guidelines For The Greater Dublin Area 2010-2022,* Dublin: Regional Planning Guidelines Office.

The Royal Society & The US National Academy of Sciences, 2014. *Climate Change: Evidence & Causes,* s.l.: The Royal Society & The US National Academy of Sciences.

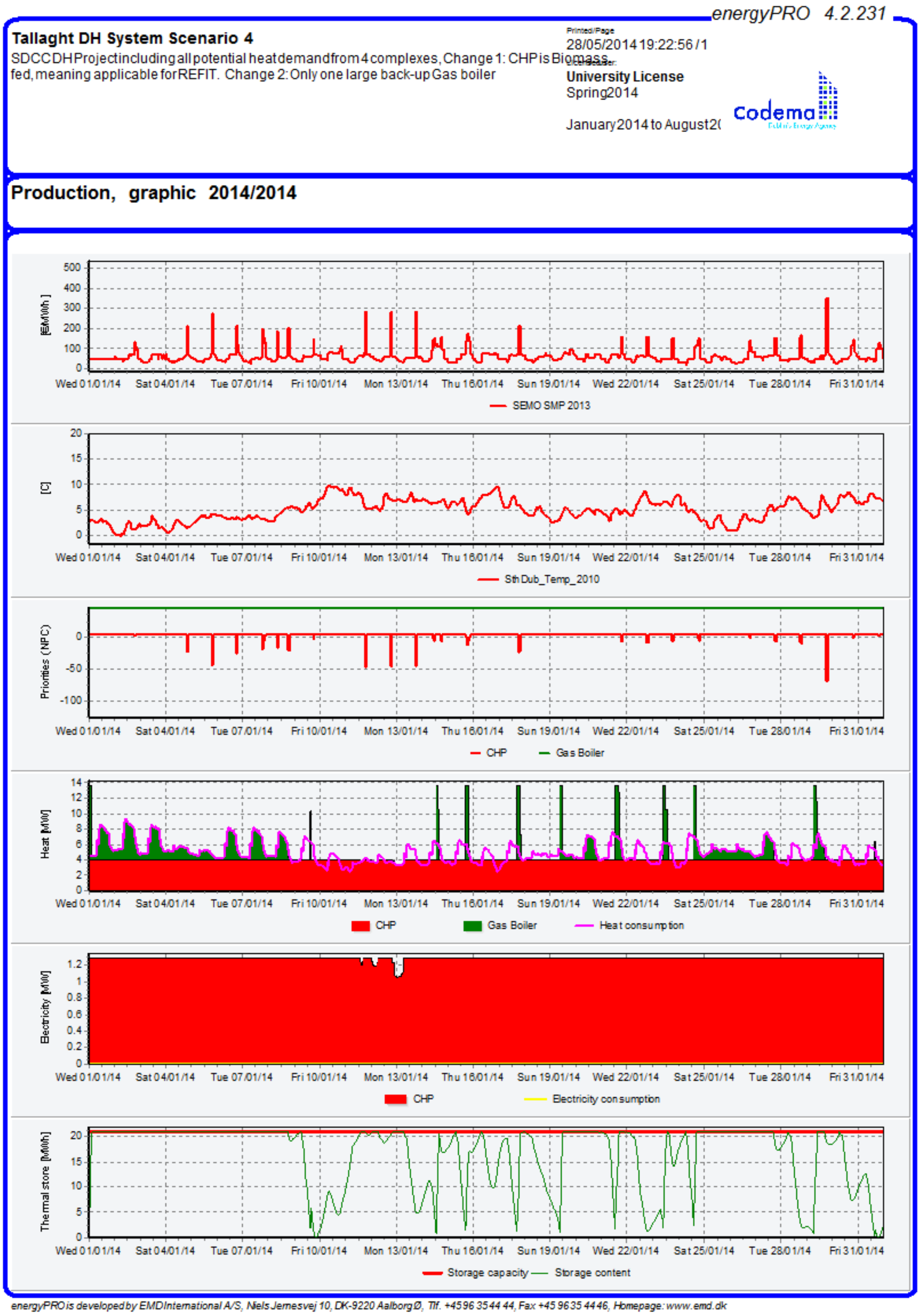
Unruh, G. C., 2002. Escaping Carbon Lock-in. *Energy Policy,* 30(4), pp. 317-325.

Weymouth, L., 2014. *Talking with Polands Foreign Minister about the Ukraine Crisis and Russia's next moves.* [Online] Available at: http://www.washingtonpost.com/opinions/talking-with-polands-foreign-minister-about-the-ukraine-crisis-and-russias-next-moves/2014/04/17/f1811e84-c5ad-11e3-bf7a-be01a9b69cf1_story.html [Accessed 21 April 2014].

WS Atkins Consultants, 2002. *Assessment of the Barrieres and Opportunities Facing the Deployment of District Heating in Ireland,* Dublin: SEI.

WYG, 2009. *Cork Docklands High Level District Heating Feasibility Study,* Cork: Cork County Council.

Results of Scenario 4 described in 'Analysis of Scenarios', p36.



energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 2
Licensed user:
University License
Spring 2014

January 2014 to August 2(

Energy conversion, annual

Calculated period: 01/2014-12/2014

Heat demands:

Hospital Heat Demand	19,292.5 MWh
Network Losses	3,879.7 MWh
SDCC Buildings	2,009.3 MWh
The Square	1,686.6 MWh
ITT	2,875.9 MWh
Total	29,744.0 MWh
Max heat demand	9.6 MW

Heat productions:

CHP	24,956.8 MWh/year	
Gas Boiler	4,809.2 MWh/year	
Heat Storage Loss (total for site)	-22.0 MWh/year	
Total	29,744.0 MWh/year	100.0 %

Electricity demands (not including electricity consumed by energy units):

Pumps	18.6 MWh
Max electricity demand	0.0 MW

Electricity produced by energy units:

SEMO Ireland:

	All periods [MWh/year]	Of annual production
CHP	7,986.2	100.0%

Peak electric production:

CHP 1,280.0 kW-elec.

Electricity exchange:

SEMO Ireland:

	Total [MWh/year]
Exported electricity, SEMO Ireland	7,968.4
Imported electricity, SEMO Ireland	0.8

Hours of operation:

SEMO Ireland:

	Total [h/Year]	Of annual hours
CHP	8,387.0	95.7%
Out of total in period	8,760.0	

Production unit(s) Not connected to electricity market:

	Total [h/Year]	Of annual hours
Gas Boiler	2,469.0	28.2%
Out of total in period	8,760.0	

energyPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, Homepage: www.emd.dk

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

University License
Spring2014

January 2014 to August 2(

codema

Energy conversion, annual

Turn ons:

CHP	19
GasBoiler	104

Fuels:

By fuel

	Fuel consumption
Gas	5,062,209.4 kWh
Woodchips	10,002,209.0 kg wet
WoodPellets	0.0 kg
Gas Oil	0.0 ltr
Electricity	0.0 kWh

By energy unit

CHP	32,007.1 MWh	=10,002,209.0 kg wet
GasBoiler	5,062.2 MWh	=5,062,209.4 kWh
Total	37,069.3 MWh	

energyPRO 4.2.231

Tallaght DH System Scenario 4
SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 4

University License
Spring2014

January 2014 to August 2(

Energy conversion, annual

Calculated period: 01/2033-12/2033

Heat demands:

HospitalHeatDemand	15,437.6 MWh
NetworkLosses	3,103.8 MWh
SDCCBuildings	1,338.9 MWh
TheSquare	1,349.6 MWh
ITT	2,288.2 MWh
Total	23,518.1 MWh
Max heat demand	7.5 MW

Heat productions:

CHP	21,733.4 MWh/year	
GasBoiler	1,806.6 MWh/year	
HeatStorage Loss (total for site)	-21.9 MWh/year	
Total	23,518.1 MWh/year	100.0 %

Electricity demands (not including electricity consumed by energy units):

Pumps	14.9 MWh
Max electricity demand	0.0 MW

Electricity produced by energy units:
SEMO Ireland:

	All periods [MWh/year]	Of annual production
CHP	6,954.7	100.0%

Peak electric production:

CHP	1,280.0 kW-elec.

Electricity exchange:
SEMO Ireland:

	Total [MWh/year]
Exported electricity, SEMO Ireland	6,940.6
Imported electricity, SEMO Ireland	0.7

Hours of operation:
SEMO Ireland:

	Total [h/Year]	Of annual hours
CHP	8,346.0	95.3%
Out of total in period	8,760.0	

Production unit(s) Not connected to electricity market:

	Total [h/Year]	Of annual hours
GasBoiler	934.0	10.7%
Out of total in period	8,760.0	

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass-fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 5

University License
Spring2014

January 2014 to August 2(

Energy conversion, annual

Turn ons:

CHP	38
GasBoiler	112

Fuels:

By fuel

	Fuel consumption
Gas	1,901,638.9 kWh
Woodchips	8,710,353.4 kg wet
WoodPellets	0.0 kg
Gas Oil	0.0 ltr
Electricity	0.0 kWh

By energy unit

CHP	27,873.1 MWh	=8,710,353.4 kg wet
GasBoiler	1,901.6 MWh	=1,901,638.9 kWh
Total	29,774.8 MWh	

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 6

Licensed user:
University License
Spring2014

January 2014 to August 20

codema

Energy conversion, summary

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Heat demand [MWh]	29,744	28,530	27,800	26,608	25,617	24,579	23,439	23,537	23,518	23,507	23,668	23,534	23,320	23,537	23,611	23,543	23,540	23,534	23,441	23,518
Electricity demand [MWh]	19	18	17	17	16	16	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Electricity produced by energy units [MWh]	7,986	7,844	7,724	7,528	7,352	7,163	6,961	6,952	6,955	6,956	6,994	6,966	6,931	6,952	6,986	6,962	6,964	6,966	6,971	6,955
Exported electricity [MWh]	7,968	7,827	7,707	7,512	7,337	7,149	6,947	6,937	6,941	6,941	6,980	6,952	6,916	6,937	6,972	6,948	6,950	6,952	6,957	6,941
Peak [MW]	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278	1.278
Imported electricity [MWh]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Peak [MW]	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Energy unit: CHP																				
Fuel consum. [kg wet]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel consum. [MWh]	32,007	31,437	30,955	30,172	29,465	28,709	27,900	27,861	27,873	27,876	28,032	27,918	27,777	27,861	28,000	27,902	27,909	27,918	27,939	27,873
Heat prod. [MWh]	24,957	24,513	24,137	23,526	22,975	22,386	21,754	21,724	21,733	21,736	21,858	21,769	21,658	21,724	21,832	21,756	21,762	21,769	21,785	21,733
Elec. prod. [MWh]	7,986	7,844	7,724	7,528	7,352	7,163	6,961	6,952	6,955	6,956	6,994	6,966	6,931	6,952	6,986	6,962	6,964	6,966	6,971	6,955
Turn ons	19	21	22	24	29	31	38	38	37	37	37	37	38	38	37	38	38	38	39	38
Operating hours	8,387	8,383	8,408	8,376	8,350	8,367	8,367	8,343	8,347	8,347	8,353	8,350	8,343	8,343	8,371	8,325	8,328	8,349	8,370	8,346
Energy unit: Gas Boiler																				
Fuel consum. [kWh]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel consum. [MWh]	5,062	4,252	3,879	3,267	2,804	2,332	1,797	1,931	1,902	1,888	1,928	1,881	1,772	1,931	1,895	1,904	1,894	1,881	1,767	1,902
Heat prod. [MWh]	4,809	4,039	3,685	3,104	2,664	2,215	1,707	1,835	1,807	1,793	1,832	1,787	1,684	1,835	1,801	1,809	1,799	1,787	1,679	1,807
Turn ons	104	83	112	95	110	96	125	92	112	116	144	121	122	92	109	144	130	121	130	112
Operating hours	2,469	2,138	2,114	1,761	1,499	1,119	998	1,046	934	941	1,064	983	984	1,046	943	1,077	1,064	983	940	934
Fuel consumption: Gas																				
Fuel consum. [kWh]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel consum. [MWh]	5,062	4,252	3,879	3,267	2,804	2,332	1,797	1,931	1,902	1,888	1,928	1,881	1,772	1,931	1,895	1,904	1,894	1,881	1,767	1,902
Peak [MW]	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105	10.105
Fuel consumption: Wood chips																				
Fuel consum. [kg wet]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel consum. [MWh]	32,007	31,437	30,955	30,172	29,465	28,709	27,900	27,861	27,873	27,876	28,032	27,918	27,777	27,861	28,000	27,902	27,909	27,918	27,939	27,873
Peak [MW]	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130	5.130
Fuel consumption: Wood Pellets																				
Fuel consum. [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel consum. [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peak [MW]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel consumption: Gas Oil																				
Fuel consum. [ltr]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel consum. [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peak [MW]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel consumption Electricity																				
Fuel consum. [kWh]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel consum. [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peak [MW]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Tallaght DH System Scenario 4

SDCCDHProjectincludingallpotential heatdemandfrom4complexes,Change1: CHPis Biomass fed,meaning applicable forREFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 /7
Licensed user:
University License
Spring2014

January 2014 to August 2(

Environment

Emissions

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
CO2[ton]																				
CHPEmission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GasBoiler	1,036	870	794	669	574	477	368	395	389	386	395	385	363	395	388	390	388	385	362	389
CO2Total	**1,036**	**870**	**794**	**669**	**574**	**477**	**368**	**395**	**389**	**386**	**395**	**385**	**363**	**395**	**388**	**390**	**388**	**385**	**362**	**389**

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 8

Licensed user:
University License
Spring2014

January 2014 to August 2(

Cash Flow, summary

(All amounts in 1000 €)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Revenues																				
SpotMarket	1,023	1,071	1,091	1,110	1,132	1,126	1,117	1,138	1,161	1,184	1,215	1,234	1,252	1,282	1,313	1,335	1,362	1,389	1,418	1,444
Sale of Heat SDCC	78	74	73	69	66	63	59	60	61	62	64	65	66	68	69	71	72	73	74	76
Sale of Heat Hospital	751	736	734	717	705	692	674	690	704	718	737	747	755	778	797	809	825	842	854	876
Sale of Heat ITT	112	109	109	106	105	103	100	103	104	106	110	111	112	116	118	121	123	125	127	130
Sale of Heat Square	66	64	64	63	62	60	59	60	62	63	64	65	66	68	70	71	72	74	75	77
Standing Charges																				
Hospital	150	147	147	143	141	138	135	138	141	144	147	149	151	156	159	162	165	168	171	175
SDCC	16	15	15	14	13	13	12	12	12	12	13	13	13	14	14	14	14	15	15	15
ITT	22	22	22	21	21	21	20	21	21	21	22	22	22	23	24	24	25	25	25	26
Square	13	13	13	13	12	12	12	12	12	13	13	13	13	14	14	14	14	15	15	15
Standing Charges Total	**201**	**197**	**196**	**191**	**188**	**184**	**178**	**183**	**186**	**190**	**195**	**198**	**200**	**206**	**211**	**214**	**218**	**223**	**226**	**232**
Total Revenues	**2,232**	**2,251**	**2,266**	**2,256**	**2,258**	**2,227**	**2,187**	**2,235**	**2,279**	**2,324**	**2,386**	**2,421**	**2,450**	**2,517**	**2,577**	**2,620**	**2,673**	**2,726**	**2,775**	**2,834**
Operating Expenditures																				
Fuel Costs																				
Gas	176	158	149	131	117	99	78	86	86	87	91	90	87	96	96	99	100	102	97	107
Woodchips	1,119	1,121	1,126	1,120	1,115	1,108	1,099	1,119	1,142	1,165	1,195	1,214	1,232	1,260	1,292	1,313	1,340	1,367	1,395	1,420
Woodpellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GasOil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel Costs Total	**1,295**	**1,279**	**1,275**	**1,250**	**1,232**	**1,208**	**1,177**	**1,205**	**1,228**	**1,252**	**1,286**	**1,304**	**1,319**	**1,357**	**1,388**	**1,412**	**1,440**	**1,469**	**1,493**	**1,527**
O&M																				
BioCHP	190	194	198	202	206	210	214	219	223	228	232	237	241	246	251	256	261	267	272	277
BiomassBoiler	26	22	21	18	16	13	10	11	11	12	12	12	12	13	13	13	13	14	13	14
DH system	23	23	23	22	22	21	21	21	22	22	23	23	23	24	24	25	25	26	26	27
O&M Total	**240**	**239**	**241**	**242**	**243**	**245**	**245**	**251**	**256**	**261**	**267**	**272**	**276**	**283**	**288**	**294**	**300**	**306**	**311**	**318**
Carbon Tax																				
CT on Gas boiler	21	17	16	13	11	10	7	8	8	8	8	8	7	8	8	8	8	8	7	8
Carbon Tax Total	**21**	**17**	**16**	**13**	**11**	**10**	**7**	**8**	**8**	**8**	**8**	**8**	**7**	**8**	**8**	**8**	**8**	**8**	**7**	**8**
Total Operating Expenditures	**1,556**	**1,536**	**1,532**	**1,506**	**1,487**	**1,462**	**1,430**	**1,464**	**1,492**	**1,521**	**1,560**	**1,583**	**1,602**	**1,648**	**1,685**	**1,714**	**1,748**	**1,782**	**1,811**	**1,853**
Net Cash from Operation	**676**	**716**	**734**	**751**	**771**	**765**	**757**	**771**	**787**	**803**	**825**	**837**	**848**	**870**	**892**	**906**	**925**	**944**	**964**	**981**
Investments																				
Bio CHP Plant	5,440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GasBoilerCosts	960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ThermalStore	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DHNetwork	1,862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GridConnection	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SiteCosts	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Admin/Applications	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FuelStorage Depot	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Investments	**8,530**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 9
Licensed user:
University License
Spring2014

January 2014 to August 2(

Cash Flow, summary

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
CashFromLongTermFinancing																				
Loan	8,530	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total CashFromLongTerm...	**8,530**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Debtservice																				
Loan	371	661	661	661	661	661	661	661	661	661	661	661	661	661	661	661	661	661	661	661
TotalDebtservice	**371**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**	**661**
Grants																				
Grant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TotalGrants	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Tax payments																				
IncomeTax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tax payments	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Interest on CashAccount	**5**	**11**	**13**	**16**	**19**	**23**	**27**	**31**	**35**	**40**	**46**	**53**	**60**	**68**	**76**	**86**	**96**	**107**	**119**	**132**
CashSurplus	**310**	**66**	**86**	**106**	**130**	**128**	**123**	**142**	**162**	**183**	**211**	**229**	**248**	**277**	**308**	**331**	**360**	**390**	**422**	**452**
CashAccount	**310**	**376**	**462**	**568**	**697**	**825**	**948**	**1,090**	**1,252**	**1,435**	**1,646**	**1,875**	**2,123**	**2,400**	**2,708**	**3,039**	**3,400**	**3,790**	**4,212**	**4,665**

energyPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, Homepage: www.emd.dk

energyPRO 4.2.231

Tallaght DH System Scenario 4

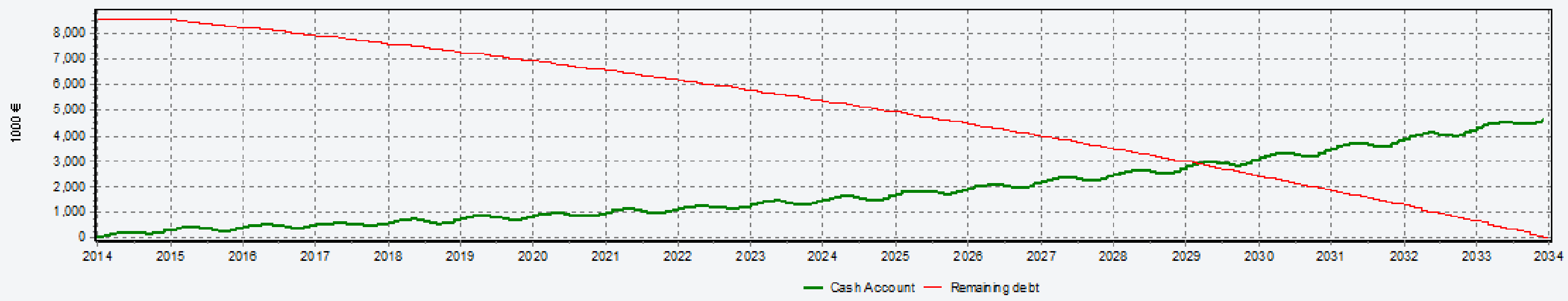
SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 10

Licensed user:
University License
Spring2014

January 2014 to August 2(

Cash Account



energyPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, Homepage: www.emd.dk

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCCDHProjectincludingallpotential heatdemandfrom4complexes,Change1:CHPisBiomass fed,meaning applicable forREFIT. Change 2:Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 11
Licensed user:
University License
Spring2014

January 2014 to August 2(

Financial Key Figures

Investment Key Figures

Internal Rate of Return (IRR), include all Payments:	:	Not found
Internal Rate of Return (IRR), include operational payments and investements:	:	7.8%
Net Present Value of		
Net cash from operation and investments	:	457,398 €
Tax payments	:	0 €
Financial payments	:	1,829,466 €
All Payments	:	2,286,864 €
(at a nominal rate of: 6.6% p.a.)		

energyPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, Homepage: www.emd.dk

energyPRO 4.2.231

Tallaght DH System Scenario 4
SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 12
Licensed user:
University License
Spring2014

January 2014 to August 2(

Income Statement, summary

(All amounts in 1000 €)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Revenues																				
SpotMarket	1,023	1,071	1,091	1,110	1,132	1,126	1,117	1,138	1,161	1,184	1,215	1,234	1,252	1,282	1,313	1,335	1,362	1,389	1,418	1,444
Sale of Heat SDCC	78	74	73	69	66	63	59	60	61	62	64	65	66	68	69	71	72	73	74	76
Sale of Heat Hospital	751	736	734	717	705	692	674	690	704	718	737	747	755	778	797	809	825	842	854	876
Sale of Heat ITT	112	109	109	106	105	103	100	103	104	106	110	111	112	116	118	121	123	125	127	130
Sale of Heat Square	66	64	64	63	62	60	59	60	62	63	64	65	66	68	70	71	72	74	75	77
Standing Charges																				
Hospital	150	147	147	143	141	138	135	138	141	144	147	149	151	156	159	162	165	168	171	175
SDCC	16	15	15	14	13	13	12	12	12	12	13	13	13	14	14	14	14	15	15	15
ITT	22	22	22	21	21	21	20	21	21	21	22	22	22	23	24	24	25	25	25	26
Square	13	13	13	13	12	12	12	12	12	13	13	13	13	14	14	14	14	15	15	15
Standing Charges Total	**201**	**197**	**196**	**191**	**188**	**184**	**178**	**183**	**186**	**190**	**195**	**198**	**200**	**206**	**211**	**214**	**218**	**223**	**226**	**232**
Total Revenues	**2,232**	**2,251**	**2,266**	**2,256**	**2,258**	**2,227**	**2,187**	**2,235**	**2,279**	**2,324**	**2,386**	**2,421**	**2,450**	**2,517**	**2,577**	**2,620**	**2,673**	**2,726**	**2,775**	**2,834**
Operating Expenditures																				
Fuel Costs																				
Gas	176	158	149	131	117	99	78	86	86	87	91	90	87	96	96	99	100	102	97	107
Woodchips	1,119	1,121	1,126	1,120	1,115	1,108	1,099	1,119	1,142	1,165	1,195	1,214	1,232	1,260	1,292	1,313	1,340	1,367	1,395	1,420
Woodpellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GasOil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel Costs Total	**1,295**	**1,279**	**1,275**	**1,250**	**1,232**	**1,208**	**1,177**	**1,205**	**1,228**	**1,252**	**1,286**	**1,304**	**1,319**	**1,357**	**1,388**	**1,412**	**1,440**	**1,469**	**1,493**	**1,527**
O&M																				
BioCHP	190	194	198	202	206	210	214	219	223	228	232	237	241	246	251	256	261	267	272	277
Biomass Boiler	26	22	21	18	16	13	10	11	11	12	12	12	12	13	13	13	13	14	13	14
DH system	23	23	23	22	22	21	21	21	22	22	23	23	23	24	24	25	25	26	26	27
O&M Total	**240**	**239**	**241**	**242**	**243**	**245**	**245**	**251**	**256**	**261**	**267**	**272**	**276**	**283**	**288**	**294**	**300**	**306**	**311**	**318**
Carbon Tax																				
CT on Gas boiler	21	17	16	13	11	10	7	8	8	8	8	8	7	8	8	8	8	8	7	8
Carbon Tax Total	**21**	**17**	**16**	**13**	**11**	**10**	**7**	**8**	**8**	**8**	**8**	**8**	**7**	**8**	**8**	**8**	**8**	**8**	**7**	**8**
Total Operating Expenditures	**1,556**	**1,536**	**1,532**	**1,506**	**1,487**	**1,462**	**1,430**	**1,464**	**1,492**	**1,521**	**1,560**	**1,583**	**1,602**	**1,648**	**1,685**	**1,714**	**1,748**	**1,782**	**1,811**	**1,853**
Depreciations																				
Bio CHP Plant	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272	272
Gas Boiler Costs	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Thermal Store	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
DH Network	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Grid Connection	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Site Costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Admin/Applications	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel Storage Depot	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total Depreciations	**481**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**	**371**

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 13
Licensed user:
University License
Spring2014

January 2014 to August 2(

codema

Income Statement, summary

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Operation Income	**195**	**345**	**363**	**380**	**400**	**394**	**386**	**400**	**416**	**432**	**454**	**466**	**478**	**499**	**521**	**535**	**554**	**573**	**593**	**610**
Financial Expenditures																				
Loan, interest and fee's	371	365	352	338	324	309	294	277	260	243	224	205	184	163	141	118	94	69	43	15
Interest on Cash Account	-5	-11	-13	-16	-19	-23	-27	-31	-35	-40	-46	-53	-60	-68	-76	-86	-96	-107	-119	-132
Total Financial Expenditures	**366**	**355**	**339**	**323**	**305**	**286**	**267**	**246**	**225**	**202**	**178**	**152**	**125**	**96**	**65**	**33**	**-2**	**-38**	**-76**	**-117**
Deferred Income																				
Grant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Deferred income	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Result Of The Year (before tax)	**-171**	**-10**	**24**	**57**	**95**	**108**	**119**	**154**	**191**	**230**	**277**	**314**	**353**	**403**	**457**	**503**	**556**	**611**	**669**	**727**
Tax payments																				
Income Tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tax payments	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Result Of The Year	**-171**	**-10**	**24**	**57**	**95**	**108**	**119**	**154**	**191**	**230**	**277**	**314**	**353**	**403**	**457**	**503**	**556**	**611**	**669**	**727**

energyPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg Ø, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, Homepage: www.emd.dk

energyPRO 4.2.231

Tallaght DH System Scenario 4

SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 18

University License
Spring2014

January 2014 to August 2(

codema

Operation Strategy Calculation (January 2014)

1. Balance price: Gas Boiler = CHP **(Elec. spot price: -4.68 €/MWh-elec)**

[All amounts in €/MWh-heat]

CHP

when exporting electricity

				1. Balance-price
Revenues				
Spot Market	0.32	MWh at	Spot =	1.50
Sale of Heat SDCC	0.00	MWh at	38.94 =	0.00
Sale of Heat Hospital	0.00	MWh at	38.94 =	0.00
Sale of Heat ITT	0.00	MWh at	38.94 =	0.00
Sale of Heat Square	0.00	MWh at	38.94 =	0.00
Standing Charges				
Hospital	0.00	MWh at	7.79 =	0.00
SDCC	0.00	MWh at	7.79 =	0.00
ITT	0.00	MWh at	7.79 =	0.00
Square	0.00	MWh at	7.79 =	0.00
Standing Charges Total				**0.00**
Total Revenues				**0.00**
Operating Expenditures				
Fuel Costs				
Gas	0.00	kWh at	0.03 =	0.00
Woodchips	400.78	kg wet at	0.11 =	44.85
Woodpellets	0.00	kg at	0.24 =	0.00
Gas Oil	0.00	ltr at	0.95 =	0.00
Fuel Costs Total				**0.04**
O&M				
Bio CHP	0.00		at 190,400.00=	0.00
BiomassBoiler	0.00	MWh at	5.40 =	0.00
DHsystem	0.00	MWh at	0.90 =	0.00
O&M Total				**0.00**
Carbon Tax				
CT on Gas boiler	0.00	MWh at	4.10 =	0.00
Carbon Tax Total				**0.00**
Total Operating Expenditures				**0.04**
Heat Production Costs				**0.05**

energyPRO 4.2.231

Tallaght DH System Scenario 4
SDCC DH Project including all potential heat demand from 4 complexes, Change 1: CHP is Biomass-fed, meaning applicable for REFIT. Change 2: Only one large back-up Gas boiler

Printed/Page
28/05/2014 19:22:56 / 20
University License
Spring 2014

January 2014 to August 2(

Operation Strategy Calculation (January 2014)

[All amounts in €/MWh-heat]

Gas Boiler

				1. Balance-price
Revenues				
Spot Market	0.00	MWh at	Spot =	0.00
Sale of Heat SDCC	0.00	MWh at	38.94 =	0.00
Sale of Heat Hospital	0.00	MWh at	38.94 =	0.00
Sale of Heat ITT	0.00	MWh at	38.94 =	0.00
Sale of Heat Square	0.00	MWh at	38.94 =	0.00
Standing Charges				
Hospital	0.00	MWh at	7.79 =	0.00
SDCC	0.00	MWh at	7.79 =	0.00
ITT	0.00	MWh at	7.79 =	0.00
Square	0.00	MWh at	7.79 =	0.00
Standing Charges Total				**0.00**
Total Revenues				**0.00**
Operating Expenditures				
Fuel Costs				
Gas	1,052.60	kWh at	0.03 =	36.63
Woodchips	0.00	kg wet at	0.11 =	0.00
Woodpellets	0.00	kg at	0.24 =	0.00
Gas Oil	0.00	ltr at	0.95 =	0.00
Fuel Costs Total				**0.04**
O&M				
Bio CHP	0.00		at 190,400.00=	0.00
Biomass Boiler	1.00	MWh at	5.40 =	5.40
DH system	0.00	MWh at	0.90 =	0.00
O&M Total				**0.01**
Carbon Tax				
CT on Gas boiler	1.05	MWh at	4.10 =	4.32
Carbon Tax Total				**0.00**
Total Operating Expenditures				**0.05**
Heat Production Costs				**0.05**

APPENDIX B

EMAIL CORRESPONDENCES

EMAIL CORRESPONDENCE TO THE GREATER DUBLIN AREA REGIONAL PLANNING AUTHORITY

- **From:** Donna Gartland [mailto:donna.gartland@codema.ie]
  Sent: 06 March 2014 17:15
  To: 'info@rpg.ie'
  Subject: Enquiry into District Heating planning guidelines: Dublin City Energy Agency

I am contacting you from the City of Dublin Energy Management Agency, where we are currently working on a District Heating project in Dublin. I am looking for any planning guidelines available relating to district heating/cooling systems in the Dublin region. I have gone through the RPG for the GDA 2010-2022, but there seems to be no mention of District Heating systems. Would you be able to tell me if there is any relating guidelines now, or is there any plans to include District Heating in future planning guidelines? Any help on this matter is much appreciated.

(This enquiry is directly related to Article 13(1) of the Renewable Energy Directive, under the National Renewable Energy Action Plan section 4.2.1 part (l), which states the Planning Authorities provide guidance documents for such renewable energy installations for electricity and heat.)

Kind regards,

Donna Gartland
Codema

Energy Researcher

t: 01-7079818
e: donna.gartland@codema.ie

- **Reply sent**: Fri 07/03/2014 16:24
  From: Malachy Bradley mbradley@rpg.ie

Donna

Regarding your query, you are correct that there is no current guidelines relating to district heating / cooling systems in the Dublin Region.

The Regional Planning Guidelines for the Greater Dublin Area 2010-2022 have polices on renewable energy section 6.6.5 refers, and there are government policies from Irelands Climate Change Strategy 2013, however there is no reference to district heating in the current RPGs.

I am aware that some of the local authorities in Dublin have looked at district heating projects, Codema may well have been involved in some of these, however it has not occurred as an issue at Regional level.

With regard to the next review of the RPGs, this will occur in the context of the new Regional Structures outlined in the Government action programme for Local Government - "Putting People First", the exact nature of these structures has not yet been finalised. However it is envisaged that the new structures will have new planning documents called Regional Economic and Spatial Strategies which will supersede the RPGs. Given that the details of the new Regional Structure have not been finalised I am not able to confirm what issues/projects/guidelines will be included in the new Strategies.

Regards

Malachy Bradley

| RPG Officer | Dublin & Mid East Regional Authorities

Unit K28 | Drinan Enterprise Centre | Swords Enterprise Park |

Feltrim Road | Swords | Co Dublin

Tel: + 353 1 8074482

Email: mbradley@rpg.ie

EMAIL CORRESPONDENCE TO ANDERS DYRELUND OF RAMBOLL CONSULTANCY, DENMARK

- **From:** Donna Gartland [mailto:donna.gartland@codema.ie]
  Sent: 1. maj 2014 15:55
  To: Anders Dyrelund
  Subject: Query: District Heating Tax

Hi Anders,

I received your contact information from David Connolly at Aalborg University, as he suggested you may be able to help me with a query regarding tax on fuel and District Heating.

I am carrying out an analysis of a proposed DH system in Ireland for the Dublin City municipality, and as part of my thesis for Aalborg University. From a financial point of view, when there is value added tax (VAT) on the fuel imported to fuel the CHP plant and back up gas boilers, the costs then must be passed on to the consumer and therefore the price of heat is not competitive with the individual gas boiler systems that are already in place. At the moment there is no heat market in Ireland and therefore there are no regulations or guidelines in place. I was wondering, in Denmark, how is this situation addressed? Is there tax exemption on fuels used for the provision of heat?

Any help on this subject is much appreciated,

Kind regards,

Donna Gartland
Codema

Research Assistant

t: 01-7079818
e: donna.gartland@codema.ie

- **Reply sent**: Fri 02/05/2014 08:13
  From: Anders Dyrelund <AD@ramboll.com>

Dear Donna

Interesting that you are working for the City of Dublin

We are very active in energy planning in several cities in England and in Scotland.

It would be interesting to exchange experience. As regards your question:

VAT is applied only on the end-use bill. All costs and tariff calculations in the DH company are made without VAT. They pay VAT on all fuel costs and costs of services etc. and they collect VAT from consumers. Each year they send the total of collected VAT minus the paid VAT to the Tax authorities

Therefore for the consumer you may compare individual costs and DH costs either without VAT or with VAT, and the % VAT is the same for all

As regards energy taxes we have high taxes on fossil fuels, and small environmental taxes on biomass. Therefore you have a competitive advantage for DH and other energy efficiency measures if you can save fossil fuels. In particular you save a lot of fuel using surplus heat from the large CHP plants. the additional fuel input to the large CHP plants for producing heat is 40- 50% of the fuel consumption for boilers, and therefore these saved fuel and tax costs gives incentives to develop heat transmission systems from the large plants in or close to the cities.

In Denmark the energy tax is now also used to generate more constant revenues to the state, and a bit more than half of the fuel which is saved at the CHP plants is now taxed.

Med venlig hilsen

Anders Dyrelund

M +45 51618766

AD@ramboll.com

CVR NR. 10160669

EMAIL CORRESPONDENCE WITH ANDERS ANDERSEN, AALBORG UNIVERSITY, VIA DAVID CONNOLLY, AALBORG UNIVERSITY

- **From:** Donna Gartland [mailto:donnagartland27@gmail.com]
  Sent: Thursday, May 22, 2014 1:39 PM
  To: David Connolly
  Subject: Quick question

Hey David,

When you get a chance, I was wondering, is there a law in Denmark which means all CHP are obliged to connect and sell to the grid, or can they use the power themselves on-site??

Talk to you soon,

Donna

- **Reply From:** Anders Andersen [mailto:ana@emd.dk]
  Sent: Sunday, May 25, 2014 2:22 PM
  To: David Connolly
  Subject: RE: Quick question

Hi David

I would say – that the simple starting point is that there "is a law in Denmark which means all CHP are obliged to connect and sell to the grid". But I consider it to be complicated legislation.

By being connected to the grid – the distributed CHP-plants gets each month a production independent premium.

But a lot of CHP-plants are allowed to make private wire operation, where they use some of the power themselves on-site. Try to google "Nettoafregning".

/Anders