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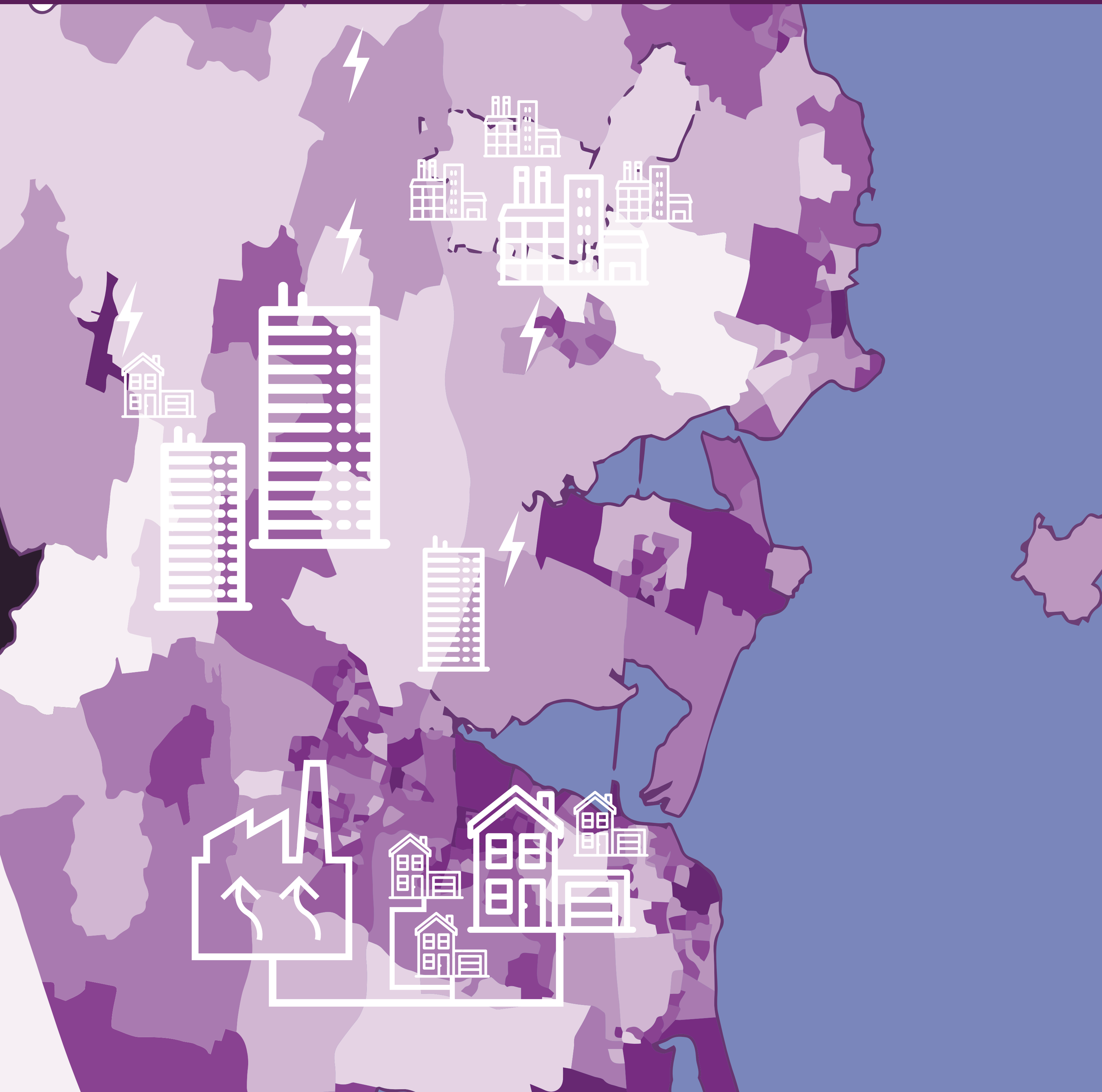
Fingal Spatial Energy Demand Analysis



Fingal Spatial Energy Demand Analysis

Report prepared by Codema on behalf of Fingal County Council

Funded by the Sustainable Energy Authority of Ireland's Research, Development and Demonstration Programme 2016, with support from the European Union and National Development Plan.

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October 2016

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Contents

Glossary of Terms

BER – Building Energy Rating
CHP – Combined Heat and Power
CSO – Central Statistics Office
DH – District Heating
FCC – Fingal County Council
GWh – Gigawatt-hour (1kWh $*10^6$)
HH – Household
km – Kilometre
kWh – Kilowatt-hour
MWh – Megawatt-hour (1kWh $*10^3$)
PV – Photovoltaic
RD&D – Research, Development and Demonstration
RE – Renewable Energy
SEAI – Sustainable Energy Authority of Ireland
SEAP – Sustainable Energy Action Plan
SECAP – Sustainable Energy Climate Action Plan
SEDA – Spatial Energy Demand Analysis
TWh – Terawatt-hour (1kWh $*10^9$)
TJ – Terajoule

Executive Summary

This is the first Spatial Energy Demand Analysis (SEDA) produced by Codema for Fingal County Council (FCC). The analysis was carried out by Codema as part of a Sustainable Energy Authority of Ireland (SEAI) funded Sustainable Energy Research, Development and Demonstration (RD&D) 2016 project to further develop the SEDA methodology, which has already been applied to the South Dublin and Dublin City areas. A SEDA involves analysing the energy demand within a given area and creates a spatial visualisation of this information, resulting in evidence-based energy maps which can be used as a tool by planners to create effective policies and actions to influence future energy use. The SEDA seeks to bridge the current gap between spatial and energy planning methodologies at a local level in Ireland, and builds on the experience of other leading European countries.

The sustainable use of energy and natural resources and the negative impacts of CO_2 on our environment have led to energy and climate change becoming a major topic in both the public and private sector discourse. The Draft Fingal Development Plan 2017-2023 identifies the importance of climate change adaptation and mitigation, and the role of sustainable energy in the county. In July 2016, FCC became the first Irish local authority to sign up to the new Covenant of Mayors for Climate and Energy. As part of this initiative, FCC will create a Sustainable Energy and Climate Action Plan (SECAP), and the results of this SEDA will support the creation of the baseline emissions calculations and energy action areas as part of this plan.

The SEDA methodology has been further developed as part of this SEAI funded project in order to more accurately map energy in a rural environment. The Fingal county area is the first region in Ireland to have spatially mapped energy use in the agricultural sector. The results of the Fingal SEDA show exactly where and what type of energy is being used, and the costs of this energy consumption throughout the county, in each of the residential, commercial, agricultural and local authority sectors. Over 90,000 dwellings, 6,000 commercial properties and 250 local authority building-based energy accounts have been analysed in terms of annual energy use, and the results have been mapped in this report. The mapping is particularly important for locating areas of high heat demand density which is a crucial element in planning for District Heating (DH) schemes.

The residential sector analysis allowed the identification of the areas in Fingal most at risk of energy poverty, based on the three most influential factors affecting energy poverty; the energy efficiency of the home, affordability (in terms of unemployment), and the cost of energy per household. These areas have been highlighted and can be prioritised in terms of strategies to combat energy poverty within the county. The results of mapping the average Building Energy Rating (BER) in each of the 938 small areas in Fingal have shown that better building regulations for new dwellings are effectively reducing the energy demand in new developments, as 53% of homes in Fingal have a BER of C or higher. However, there are certain areas, such as the Portrane Demesne which have an aging, less efficient housing stock, with average BERs of E or lower.

Of all building energy demands, heat demand accounts for 75%, and there are almost no indigenous, sustainable resources used to provide this heat. Thus, when identifying sustainability strategies, heat technologies should be of first priority in all sectors. One solution to this issue is the development of sustainably fuelled district heating networks in areas of high demand. In terms of DH analysis, there are a number of residential/commercial areas, such as Swords and Blanchardstown, with heat densities high enough to be considered feasible for connection to DH systems. Additionally, there are a number of industrial estates and commercial glasshouses situated on the outskirts of these urban hubs that could also be connected to these networks. The SEDA has also identified locations of potential anchor loads and waste heat resources which can be major contributors to a successful DH network.

Overall, Fingal spends over €331 million a year on energy and a large percentage of this money leaves the Irish economy to pay for fossil fuel imports. Therefore increasing indigenous energy sources is crucial, and this report has identified solar energy resources as one of the most accessible renewable energy resources in the dense urban areas of Fingal. There is also high potential for the growth of energy crops in much of Fingal, in areas outside of the urban centres.

Introduction

The following report has been produced by Codema on behalf of FCC and outlines the process and results of the Fingal SEDA. This analysis has been conducted by Codema as part of a project funded under the SEAI's RD&D 2016 call. The project aims to advance spatial energy demand analysis methods in Ireland so that they are more applicable to the semi-rural and rural areas found in DLR and Fingal county areas.

This SEDA aims to provide the information required for the local authority to increase the uptake of renewable energy through planning, policy and raising awareness. Up to now, the local authority has lacked any evidence-based tools for planning for sustainable energy solutions. This SEDA aims to bridge the gap between energy planning and traditional urban planning within the local authority, and enables planners to build meaningful energy policy and effectively shape the energy future of the county.

The analysis focuses on the current energy demand and the fuels that are used to provide such energy within the Fingal area, and places this data within a spatial context. Creating these maps helps to identify opportunities, synergies and constraints in different county districts. This detailed mapping process provides a visualisation of many aspects of energy use and its effects within each small area[1] in Fingal, such as:

- Building Energy Ratings
- Energy use per dwelling
- Energy spends per dwelling
- Fuels used for heating dwellings
- Areas of high commercial energy use
- Areas at risk of energy poverty
- Areas of high fossil fuel usage
- Areas with high electrical usage
- Heat demand density

These maps provide the local authority with the information needed to target areas most in need of, and most suitable for, Renewable Energy (RE) solutions. In particular, the areas with high heat demand density which are deemed most suitable for large scale DH schemes are identified. DH schemes are a proven way to integrate high levels of RE into dense urban areas such as those found in many parts of Fingal.

This SEDA is only one of four to be developed in Ireland and is seen as the next coherent step to prepare the SECAP for FCC. The SEDA enhances the SECAP in order that it can be more effectively integrated with other action plans and into the planning process. This will bring energy planning in FCC more in line with other European cities that are leading the way in effective local level sustainable energy planning.

Context

Climate Change Challenge

"Climate change is not an abstract phenomenon featuring in arcane science journals and measured only in laboratories. It is present everywhere and perhaps most harshly and adversely in environments where people are least equipped to meet its force and ill effects – and least responsible for its causes."- Michael D Higgins, President of Ireland

Climate change is widely recognised as the greatest environmental challenge of our time and the evidence of such change is already being felt here in Ireland in terms of rising sea levels, extreme weather events and changes in ecosystems. A recent publication co-authored by the UK's Royal Society and the US National Academy of Sciences, '*Climate Change: Evidence & Causes*', states that the speed of global warming is now 10 times faster 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 report also concludes 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 publication is just one of a multitude of evidence and research-based papers which show irrefutable evidence that Greenhouse Gases (GHGs) are responsible for climate change and it is imperative to act now in order to curtail the irreversible damage caused by these emissions.

Fossil fuel use is responsible for over half of all GHG emissions globally, and the majority of these emissions come from energy supply, transport, residential and commercial buildings and industry (IPCC, 2007).

The Irish Government has already committed to reducing emissions at a national level, and the significance of Fingal in the Irish economic landscape means it is imperative to plan and commit to energy saving and CO_2 reduction at a local level in order to help meet national level targets from a bottom-up approach. It is particularly important for urban regions to look to integrate renewable electricity sources as close to the demand as possible, which leads to reduced losses during transport of renewable electricity. This also has the significant effect of

[1] A 'Small Area' is the smallest geographical breakdown used in Ireland for statistical purposes.

decreasing the burden on rural areas to produce renewable electricity, particularly in the midlands and the west, where large wind farms can in some cases have negative impacts on these communities.

There are many significant additional benefits to reducing CO_2 levels and implementing more renewable energy in Fingal, including reduced health effects, decreased fossil fuel dependence, higher security of supply, lower energy costs, increased energy price stability, increased economic competitiveness and a sustainable economy.

Local Level Energy Planning

Conventionally, energy planning is implemented at a national level and not effectively addressed within local or regional level planning structures in Ireland. Experience from other countries has shown that national policies on energy which are specifically designed to address energy use from a national level perspective can make it hard for local authorities to fully address energy consumption due to the structure of the national policy framework, and the lack of autonomy and flexibility conferred upon them in the energy sector (Sperling, Hvelplund, & Mathiesen, 2011) (Chittum & Ostergaard, 2014). This leads to local authorities not having the knowledge or experience to make strategic decisions on how energy is or will be provided in their locality.

In contrast, local level energy planning is routine in many other European countries, in particular Denmark, Sweden and recently re-municipalised areas in Germany. Laws were first introduced in Denmark in 1979 requiring municipalities to carry out local level energy plans, and this regulatory framework has been credited with creating the base for the sustainable growth Denmark has seen in the years since. These planning laws required municipalities to conduct analyses of their local heating requirements and the available heat sources, and municipalities were also made responsible for assessing future heating needs and supplies and planning around these. In the 1980s, the government introduced laws to ensure that all energy projects had to be assessed by taking account of the full socio-economic costs and benefits, and based on this, municipalities should only pursue projects which show a high level of socio-economic benefits (Chittum & Ostergaard, 2014).

These laws resulted in high levels of locally produced heat and electricity in the form of Combined Heat and Power (CHP) and DH systems with integrated renewable energy sources. Today, around two thirds of Danish electricity is cogenerated with heat, and heat is supplied through DH systems to 60% of Danish households. Studies have shown that this increased use of CHP and DH has reduced overall nationwide emissions by 20%, and reduced CO_2 emissions in the heating sector by 60%. There is currently 386,234 m^2 of solar heating being used in municipal DH projects, along with other sustainable sources such as biomass and waste heat. The use of local energy planning in Denmark has reduced energy costs to consumers, enabled higher integration of renewable energy, reduced energy demand and reduced the overall impact on the environment.

The Need for Integrated Energy and Spatial Planning

The increasing need for society to change to more sustainable forms of energy supply to combat climate change and meet growing demands means that space is now a fundamental asset for energy production. This is due to the fact that renewable energy is an area-dependent resource, e.g. space and suitability of land for bio-fuel crops, for wind farms, for solar energy, or for hydro-power. (Stoeglehner, Niemetz, & Kettl, 2011). Energy production now enters the competition for space with many other products and services that are reliant on space, such as food production and property development.

Also, the feasibility of DH and CHP systems is dependent on many spatial and urban planning related factors such as heat demand density and zoning of building uses, which reinforces the inseparable nature of spatial planning and energy planning.

In order for planners to evaluate the feasibility of integrating a range of renewable energy resources, they will need to develop a SEDA type tool in order to 'read the energy landscape' (Pasqualetti, 2013). A SEDA allows planners to locate where the large energy demands are, what type of energy is required in these locations, i.e. heat, electricity, gas, etc., the areas susceptible to energy poverty due to high energy costs, and areas of high fossil fuel use.

Economic development in Dublin has been, so far, driven mainly by resources that have no immediate geographic link to the area exposed to planning. The fossil fuels and electricity that will be used during the lifetime of a development have, in most cases, no influence on its location as it can be simply connected by pipe or cable to some far-off location. In this way, spatial planning is not currently linked to energy resource management. The planning system now faces the new challenge of taking account of, and creating balance between, designing cities to reduce energy demand, retaining sufficient space for sustainable energy production, and providing energy from local resources, while also evaluating social and environmental considerations.

Spatial Energy Demand Analysis as a tool for Sustainable Spatial Planning

Energy mapping resources are used by energy planners in local authorities throughout Europe and are often referred to as the first step in the energy planning process. It is the foundation for planning for current and future predicted energy consumption at a local level. It allows the planner to define 'energy character areas', based on the estimated energy demand and supply characteristics, and the RE potential of that area.

There are many examples of best-practice energy mapping from European towns and cities, such as the London Energy Map[2], the Amsterdam Energy Atlas[3], and the Scotland Heat Map[4]. An example of the London Energy Map is shown in Figure 1.

The Swedish Energy Agency's guide to sustainable spatial planning outlines how *"integrating energy issues for heating and transport in comprehensive planning"* is one of the four 'leaps' to effective sustainable energy planning, and documenting the current energy effects of heating, cooling, electricity and transport allows the development of future scenarios for energy and transport (Ranhagen, 2011).

These maps are then used by the municipality's energy planners to decide which areas are most suitable for DH or individual heating solutions such as heat pumps or solar thermal, and integrate the findings into future scenario development. This Fingal SEDA uses similar methodologies for mapping energy demands to those that are typically used in Swedish and Danish energy planning.

Once this initial step is complete, deeper techno-economic analysis and energy system modelling of an identified energy character area allows the planner to judge if the area is technically and economically feasible to implement the recommended sustainable energy solutions.

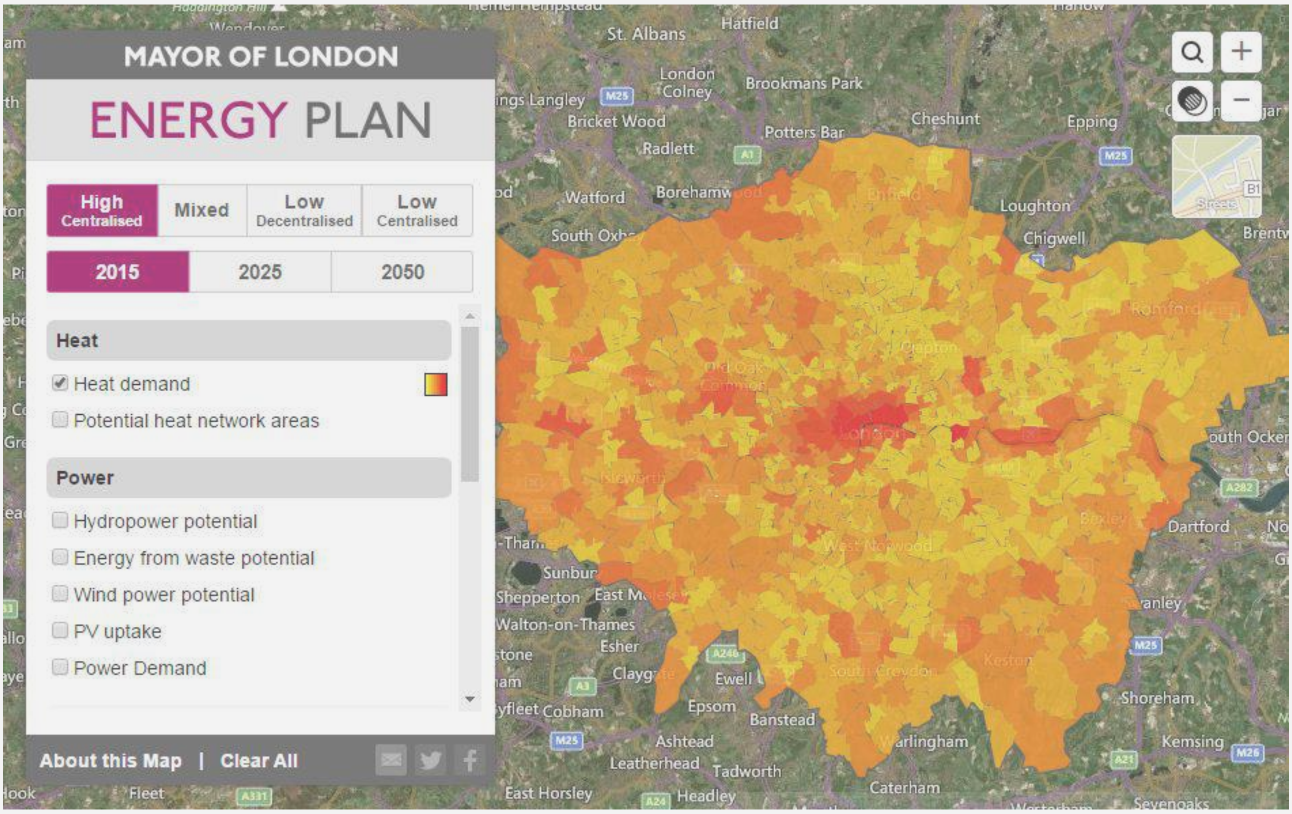

Figure 1: Heat Demand Map of London City

[2] https://www.london.gov.uk/what-we-do/environment/energy/scenarios-2050-london-energy-plan
[3] http://maps.amsterdam.nl/
[4] http://heatmap.scotland.gov.uk/

Relating Policy

EU Policy

The European Union (EU) puts in place a framework for energy for all member states called the *'2020 Climate and Energy Package'*. This set binding legislation for all member states so that the EU as a whole will achieve 20% GHG emission reductions, 20% energy produced by renewable resources, and 20% increase in energy efficiency by 2020.

From this overarching EU climate and energy package, there are directives which set specific targets for renewable energy for each member state and outline the measures to be put in place for energy efficiency.

The EU Energy Efficiency Directive 2012/27/EU, and Renewable Energy Directive 2009/28/EC have resulted in national level energy action plans in each area respectively. In terms of the Renewable Energy Directive, Ireland has been set a target of 16% of all non-Emission Trading Scheme (ETS) energy consumption to come from Renewable Energy Sources (RES) by 2020, the sectorial split being 40% electricity, 12% heat and 10% transport energy. Latest figures (2014 energy figures) show Ireland's renewable energy in electricity is at 22.7% of gross electricity consumption, renewable heat is at 6.5%, and renewables in transport at 5.2%. Therefore, Ireland is approximately half-way towards 2020 targets with four years left to improve. This SEDA aims to increase the use of renewables at a local level in order to contribute towards overall national level targets.

Although there are no binding targets for energy efficiency, there are binding obligations on each member state. Of particular relevance to this regional level SEDA, Article 14 of the Energy Efficiency Directive on the 'Promotion of efficiency in heating and cooling' states:

"*Member States shall adopt policies which encourage the due taking into account at local and regional levels of the potential of using efficient heating and cooling systems, in particular those using high-efficiency cogeneration. Account shall be taken of the potential for developing local and regional heat markets.*"

The SEDA will help to identify the most appropriate sustainable energy solutions for heating the current and future building stock in Fingal.

In October 2014, due to there being no clear framework post-2020 targets, the EU put in place a new '*2030 Framework for Climate and Energy Policies*', which has set a 40% GHG reduction on 1990 GHG levels, and an EU-wide target of 27% for renewable energy and energy savings by 2030. Under this framework, Ireland has a binding national target of 20.4%[5] reduction compared to 2005 emission levels. The new GHG targets are aimed at the non-Emissions Trading Scheme (ETS) sectors, which cover transport, buildings, agriculture, waste, land-use and forestry.

Of these sectors, transport and buildings are the largest contributors of emissions from fossil fuel consumption, and heating is the largest energy use in buildings. For example, 75% of the average household's final energy consumption is used for space and water heating (SEAI, 2013). There now needs to be a stronger focus on energy efficiency and renewable fuel sources in the heating sector in order to reduce energy related GHG emissions and contribute to meeting Ireland's binding EU 2020 and 2030 targets.

This SEDA will also allow FCC to stay on top of energy issues and help to future-proof the county for new energy legislation past 2020.

National and Regional Level Policy

The National Renewable Energy Action Plan (NREAP) and National Energy Efficiency Action Plan (NEEAP) are a direct result of the overarching EU Directives previously discussed. These outline how Ireland intends to implement the energy efficiency and renewable energy targets set by the European Commission. This SEDA aims to help fulfil the goals of the NREAP and NEEAP by developing renewable energy and energy efficiency at a local and regional level within Fingal, and developing strategic energy action plans specifically tailored to the energy characteristics of the area.

The Department of Communications, Energy and Natural Resources[6] outlines the pathway to 2030 in the report "*Ireland's Transition to a Low Carbon Energy Future 2015-2030*" and addresses priorities areas relating to energy policy:

- Empowering Energy Citizens
- Delivering Sustainable Energy
- Energy Security
- Regulation, Markets and Infrastructure
- Energy Costs
- Innovation and Enterprise

[5] The GHG target is 30%, but there have been allowances for land-use and ETS flexibility which will reduce the overall target to approximately 20.4%.

[6] Now known as the Department of Communications, Climate Action and Environment

The SEDA will help to address the priorities surrounding planning essential energy infrastructure and creating a more sustainable energy system within Fingal. The SEDA allows FCC to take some control and have some influence over the energy used within the region, which can now be used as a bottom-up approach to meeting the new energy policy priorities.

The Regional Planning Guidelines for the Greater Dublin Area (GDA) 2010-2022 provide planning guidance on economic, infrastructure and settlement policies for the GDA which includes Fingal. These guidelines specifically support the implementation of local level energy action plans, and also suggest they "*… should be presented in a spatially geographic manner where possible in order to provide an extended evidence base in the decision making process*".

This SEDA will fulfil these suggestions under the Regional Planning Guidelines, and FCC will be one of the first local authorities to do so, and which will pave the way for other local authorities to follow suit.

Analysis of District Heating Potential

DH is a key technology for urban regions to decarbonise their heat supply. '*A Guide to District Heating in Ireland*' (Gartland & Bruton, 2016) is a good source of information on the basics of DH and how DH can be developed in Ireland.

The heat consumption will be shown in terms of 'heat density', as the areas mapped vary in size and it is important to compare all on an equal parameter, such as terajoules (TJ) per km^2. Mapping heat density is important as it is a key metric for defining the potential for large scale DH.

It is important to analyse DH potential as heating and cooling are fundamentally local and regional matters, and are often not dealt with effectively at a national level. Danish municipalities carry out heat planning studies and judge an area to be suitable for DH based on the measurement of heat density, usually given in TJ/km^2, with any areas measuring above $150TJ/km^2$ deemed technically and economically suitable for developing conventional DH systems. The density is specifically important for DH economic viability as it becomes cheaper to implement when buildings are closer together due to shorter pipelines requiring less investment costs, and therefore the system becomes more cost-effective than individual solutions (Connolly, et al., 2014). Also, shorter pipelines result in fewer losses and less pumping requirements, which can reduce running costs significantly.

There are currently no large scale DH systems in Ireland, and little or no financial or policy supports for DH systems. Due to this lack of experience, and difference in support mechanisms between Denmark and Ireland, it is better to look to first-phase development of large scale DH in areas with the highest heat demand densities available. The Danish 150 TJ/km^2 threshold can then be used once a large scale DH scheme has been initiated and looking to expand. Increasing the minimum density threshold for viability will also allow for potential errors in energy estimations made in this study.

With a DH system there is opportunity to use heat from one or many sources, which may or may not rely on the location's characteristics. Fuel can be imported in most cases to fuel boilers or CHP units, but will be better placed if close to major road networks for oil or biomass deliveries. Waste heat[7], mainly sourced from industrial processes, is an ideal input into DH systems as it is a potentially low cost source and utilises energy that would otherwise be considered a loss, therefore increasing efficiencies. There are likely to be many industrial process waste heat resources in the county, such as waste heat from existing power plants, breweries and waste water treatment plants, and the potential to use such resources in Fingal should be investigated further. Other low cost fuels for DH systems can come from geothermal sources, heat pumps or solar thermal farms which are now common-practice solutions in Danish low temperature DH systems. Smart grid enabled electric boilers and heat pumps incorporated in DH supply systems which are timed to switch on/off when electricity prices are low/high can take advantage of low electricity costs and also help to integrate more fluctuating renewable energy on the grid.

Local Electricity Production Potential

The regulations in Ireland forbid the provision of what is termed a 'private wire network'. This means that you may not supply electricity to other buildings which are not on the same property as the building which is producing the electricity. This means, if a building is producing electricity and there is a surplus to what they require to cover their own demand, they must release this surplus electricity through the national grid, or store in some way for their own future use. There are possibilities for large producers to establish contracts and sell this surplus to the grid, but there is

[7] Waste heat is heat which is lost to the atmosphere during industrial and manufacturing processes, rather than heat obtained from waste.

currently no electricity supplier offering payments[8] for surplus energy to micro-generation[9] units.

This means, when analysing electricity demand of buildings and possible local sustainable solutions to meet this demand, it will be in terms of individual systems per building rather than in terms of group electricity schemes. This limits the possibilities for technologies such as CHP units as they will be more suited to industrial or large commercial consumers who have large electrical and heating requirements, and who can apply for grid connections, or in large district heating systems where the sale of electricity to the grid can help to offset the costs of heat production.

In terms of individual building renewable electricity solutions, the main technologies used which are at an advanced stage are wind turbines, solar photovoltaic (PV) panels and hydro-power turbines. The potential to use these technologies will depend on the building's location in terms of space for wind turbines and wind speeds, south-facing roof space and over-shading, and proximity to a suitable hydro source, respectively. Biomass-fed CHP units are another alternative to producing renewable electricity, and are not dependent on locational characteristics, as biomass can be imported like any other fuel. Again, biomass CHP units are more suited to commercial or industrial circumstances than households due to high upfront costs and the size of demand needed to ensure economic viability.

Energy Character Areas

Energy demand mapping is used as a tool in energy planning to define energy character areas. The individual energy characteristics of an area are used by planners to define the appropriate energy solutions or planning policies to be considered for strategic development zones, local area plans or county-wide development plans.

For example, an area with mature residential dwellings in low density suburbs can often have poor thermal performance and therefore high heat demands per building. In most cases, these areas have little variety of building use and many different building owners, which make it less favourable for communal energy solutions and more suited to individual micro-generation technologies such as solar thermal and heat pumps.

In contrast, town centres or areas of regeneration which have a high building density made up of old and new buildings with mixed use such as hotels, offices, retail and apartments, are more suited to development of large scale heating and cooling networks. Although there will be numerous building owners and facilities managers involved, these building types are likely to be accustomed to the processes involved in procuring energy services and therefore will be more likely to engage in projects offering energy savings.

Once these areas have been defined as suitable for individual or group energy schemes, the energy character areas can be defined further by overlaying renewable energy potential mapping in order to see which areas are most suitable for development of RE supply. For example, areas suitable for group energy schemes which are located in peripheral semi-rural areas may be situated close to bio-fuel supplies produced within the region, and can therefore agree long term supply contracts with local suppliers and benefit from low transport costs.

It is important to note that the resulting specific energy characteristics of each small area will have a different best-fit energy solution, which may incorporate energy savings and/or a mixture of technologies. There is no one definitive energy solution that is applicable to all areas, and once an area is identified for further investigation it is important that all available solutions are evaluated in terms of socio-economic cost-benefits. The main attributes to consider when assessing the economic feasibility of implementing various energy solutions will be the availability and suitability of low cost renewable sources in the area, the cost to retrofit current energy systems, and the current and predicted future costs of the fuel source being replaced.

All energy data used in this SEDA is based on delivered energy and not primary energy consumption, and therefore losses involved in delivering the energy, i.e. electricity transmission grid losses, are not accounted for.

The following sections in this chapter outline the results and methodologies of each area of energy use, namely residential, commercial, agricultural and municipal building energy, and the overall total energy use in Fingal.

[8] There was a payment available through application to the ESB for micro-generation, but this scheme ceased in December 2014.
[9] Micro-generation is termed as generators rated up to 25 Amps on single-phase systems (most household systems are single-phase) or 16Amps on 3-phase systems (ESB, 2015).

Spatial Energy Demand Analysis

Introduction

This section outlines the methods and results of calculating and mapping current energy consumption in buildings within the Fingal area. Currently there is no publicly available actual energy consumption data for every building in Fingal, and therefore a methodology was devised in order to estimate energy use in every building based on best available evidence based data, and attach this information to a geographic location to visualise it spatially. The methodology was developed by Codema for South Dublin and Dublin City's SEDA, and this analysis follows the same methodological process. A new methodology was developed specifically for the energy mapping of Fingal in order to quantify and map the energy use within the agricultural sector. This is the first time this sector's energy consumption will be analysed at this detailed level, and the methodology is described further in this report. The data is accumulated and analysed through the use of MS Excel software and mapped using QGIS open-source mapping software.

From analyses of spatial demand mapping practices in other countries, and the availability of matching data across all sectors, the main sets of energy data which will be created and mapped are:

- Total Energy Demand
- Total Heat Demand
- Heat Demand Density
- Total Electricity Use
- Total Fossil Fuel Use
- Total Annual Energy Costs

There will also be a breakdown of the energy use into the four sectors of Residential, Commercial/Industrial, Agricultural and Municipal energy use, which will each have their own relevant maps created. For the residential sector, there will be additional maps created, for example, showing average BER ratings in each area and areas at high risk of energy poverty. These maps will outline areas in need of energy retrofitting and areas which may be suitable for various energy technologies.

The residential data acquired from the Central Statistics Office (CSO) is aggregated by the geographical breakdown of 'Small Areas' (SA). A SA is an area of population comprising between 50 and 200 dwellings, created for Ordnance Survey Ireland (OSI) and the CSO, and is designed as the lowest level of geography for the compilation of statistics. Within the small and densely populated urban areas, SAs provide a very suitable method of mapping spatial energy demand. However, when mapping the more rural areas in Fingal, it can be difficult to assess where the demand is concentrated within these large, sparsely populated SAs. For this reason, the energy demand of Fingal will primarily be mapped on a 500m x 500m grid, developed for the purpose of this report.

This report presents Fingal's energy consumption over 2069 individual grid squares. This gives a more refined spatial breakdown than 941 individual SAs. Additionally, the uniformity of the grid distribution means that each square is directly comparable. This is particularly important when assessing heat density for district heating purposes. As can be seen in Figure 2, this scale of grid format provides a more detailed level of analysis for the large SAs and a more amalgamated breakdown for the smaller, more densely populated SAs. As the European standard is to perform Spatial Energy Demand Analyses on a 1km x 1km grid, it is considered that a 500m x 500m grid will provide satisfactory detail in results while also relating to the scale of Fingal.

The commercial and municipal energy calculations include location point specific information, thus making it easy to attach and amalgamate to any grid size. However, it is necessary to attribute the aggregated residential energy demand of the SAs into a grid of similar proportions. This is achieved by breaking down all SA shapes into small grid squares. Each grid square is then assigned a portion of the SA's residential energy information, proportionate to the level of housing present in this grid square. The level of housing is determined using a digital (OSI) map, showing building footprints in Fingal. This provides a more accurate level of spatially related energy demand for all sectors.

While the grid format is used as the primary means for representing energy information in this report, the initial five maps will be presented using SA breakdowns. The reason for this is that these maps, (Figures 6, 8, 9, 10 and 11), all represent information either solely dealing with BER data or data which is calculated "per household". This means that this information is intrinsically linked to SA data and presenting the information on grids would serve no additional purpose other than pixelating the image.

Figure 2 : Map Showing Example of Small Area (SA) Breakdown (left) and Grid Breakdown (right) in Fingal

Energy Use in Fingal

Using the current European best practice methodologies in energy demand analysis, it is possible to calculate the overall energy use for all buildings in Fingal. This is broken down for each sector in total energy demand, heat demand and annual costs in Table 1.

As is evident in Table 1, the residential sector accounts for the largest portion of energy consumption in Fingal, at 50%. However, there is also a significant amount of commercial activity present, primarily in industrial facilities located in large industrial estates such as Ballycoolin. This serves to spatially disperse the energy demand away from the urban hubs of Swords and Blanchardstown. The addition of a considerable agricultural sector, including high energy consuming horticultural glasshouses, further decentralises the consumption of energy away from these built up areas. The interaction of energy consumption between the various sectors will be examined in the following sections.

The latest figures estimate that less than 3% of all building energy use in Fingal comes from locally produced renewable energy, as shown in Figure 3, and instead there is a large dependence on imported fossil fuel sources such as gas and oil. The 3% 'other' fuel used in buildings includes peat, biomass and other renewable sources such as solar thermal. There is access to the gas grid in most urban areas of Fingal, and gas is therefore the main heating fuel, with oil being the dominant heating source in the more rural areas of Fingal. The national electricity supply is also based predominantly on gas-fuelled power plants. This means Fingal is very susceptible to price increases and

Sector	Total Energy (TWh)	Total Heat (TWh)	Total Costs (€millions)
Residential	1.99	1.70	170.78
Commercial	1.38	0.76	143.27
Municipal	0.03	0.01	2.46
Agricultural	0.62	0.53	15.29
Total	4.02	3.00	314.52

Table 1 : Representation of BERs in Each Postcode Area

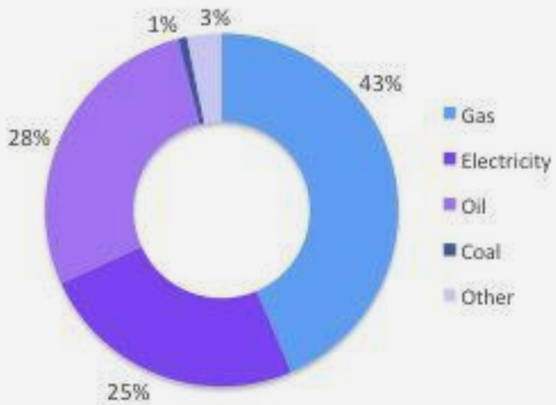

Figure 3: Final Energy Use in Buildings by Fuel Type Fingal

shortage of supply of gas in the European market. Ireland imports around 95% of its natural gas requirements[10], meaning billions of euros are exported to pay for these resources every year. If Fingal could increase its ability to meet even a small percentage of its energy demand with local sustainable resources, it could retain a substantial amount of money within the Irish economy and increase security of supply.

Electricity in Ireland has high CO_2 emissions per kWh due to the supply mix on the national grid, which, in addition to gas (~50%), is supplied by peat (12%) and coal (25%) plants. Added to this, nearly 50% of the energy from these fuels is lost during transformation and transmission. The high cost of electricity, along with high carbon emissions and reliance on imported fuels are only more reasons for Fingal to look to producing its own sustainable energy locally.

BER and Household Analysis

While the commercial and agricultural sector account for substantial portions of the energy use in Fingal, the largest contributor is the residential sector. The residential sector also provides the most detailed results due to the comprehensive data sources available. From the CSO 2011 Census, it is possible to analyse the housing stock by type, period built and spatial distribution per small area. The breakdown of the total Fingal housing stock is shown in Figure 4.

The most common housing type in Fingal is semi-detached housing, accounting for 44% of total households, with 30% built in the period 1971-1990. Next to this, the effects of the early 2000s construction boom can be seen, as 27% of all households in Fingal were built between 2001 and 2005. In the two most recent construction periods, apartments have been the most built housing type. Apartments will have a lower external wall exposure than other dwelling types, such as detached or semi detached, thus requiring less space heating per square metre and resulting in a better BER rating.

From the application of actual BER data further described in the Residential Sector Methodology, it is possible to produce a graph of estimated BER ratings for the entire housing stock in Fingal. The graph in Figure 5 shows the number of dwellings in each BER rating according to the type of dwelling. Of these, 47% are calculated to have a BER of C, which is by far the most common rating. 18% of all households have a BER rating of E or lower.

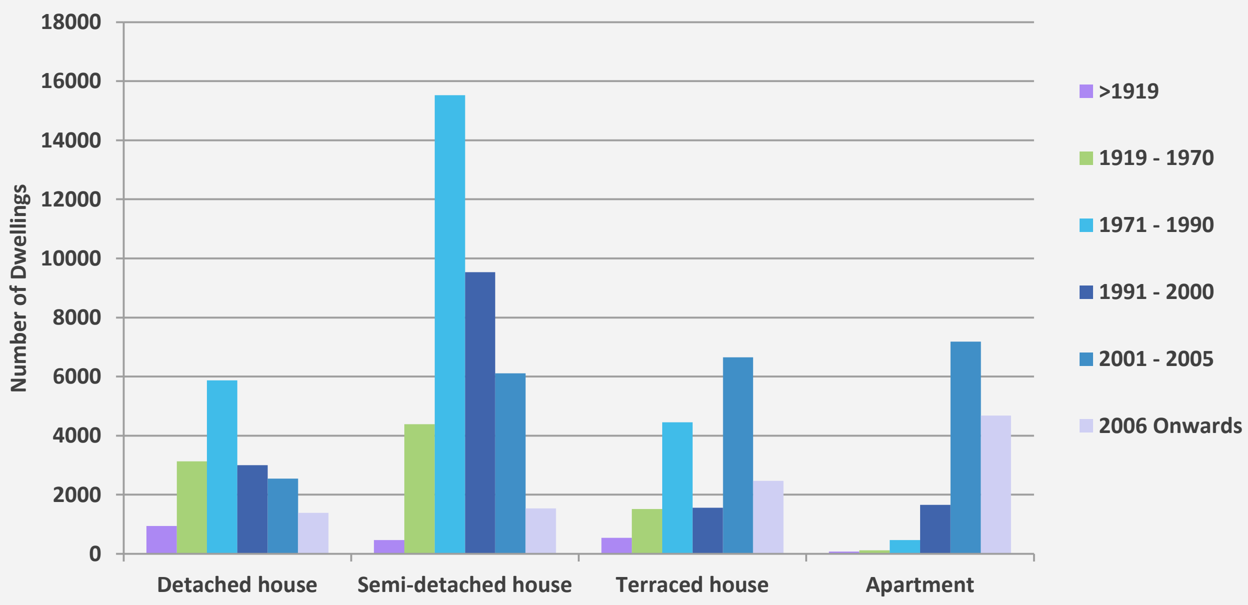

Figure 4 : Fingal Housing Stock by Type and Period Built

[10] This is currently lowered due to the production of gas at Corrib, but will return to previous import capacities when this resource runs out, predicted to be 3-4 years.

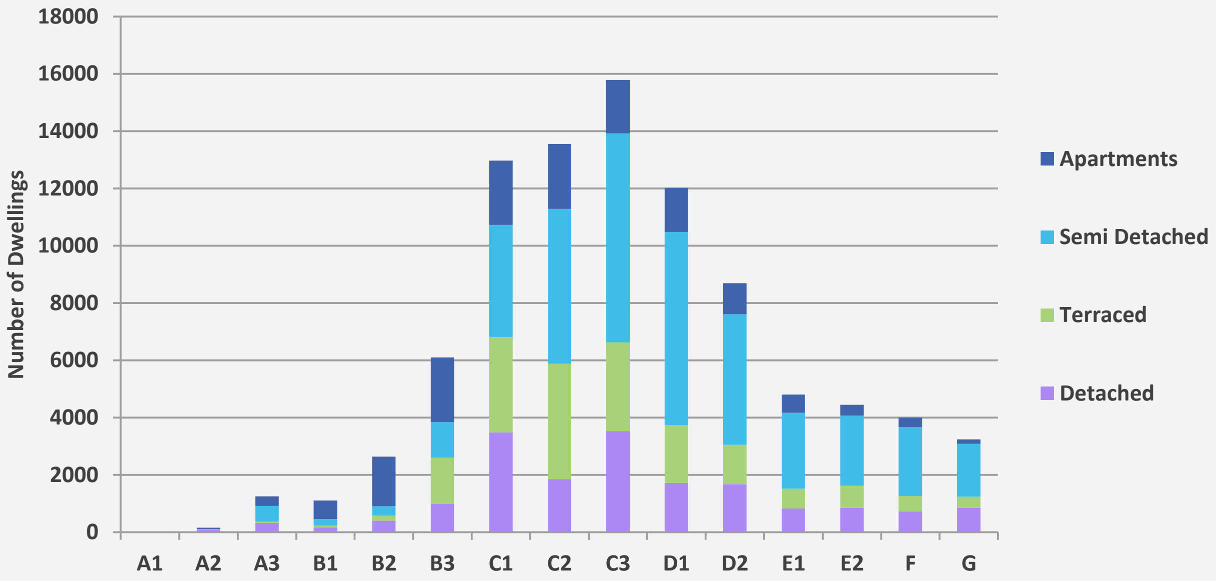

Figure 5 : Building Energy Ratings for all Fingal Households per Building Type

The graph in Figure 6 shows the energy ratings of all Fingal housing according to period built. A direct correlation between the construction year and energy rating can be seen as the lower F and G ratings are dominated by pre 1970 builds, while all A rated properties were built post 2006. It is the lower rated, old households that should be given first priority in any plans for energy efficiency upgrades in order to move them from the lower ratings up to at least high D or C ratings. This will also help to improve situations for those at risk of energy poverty.

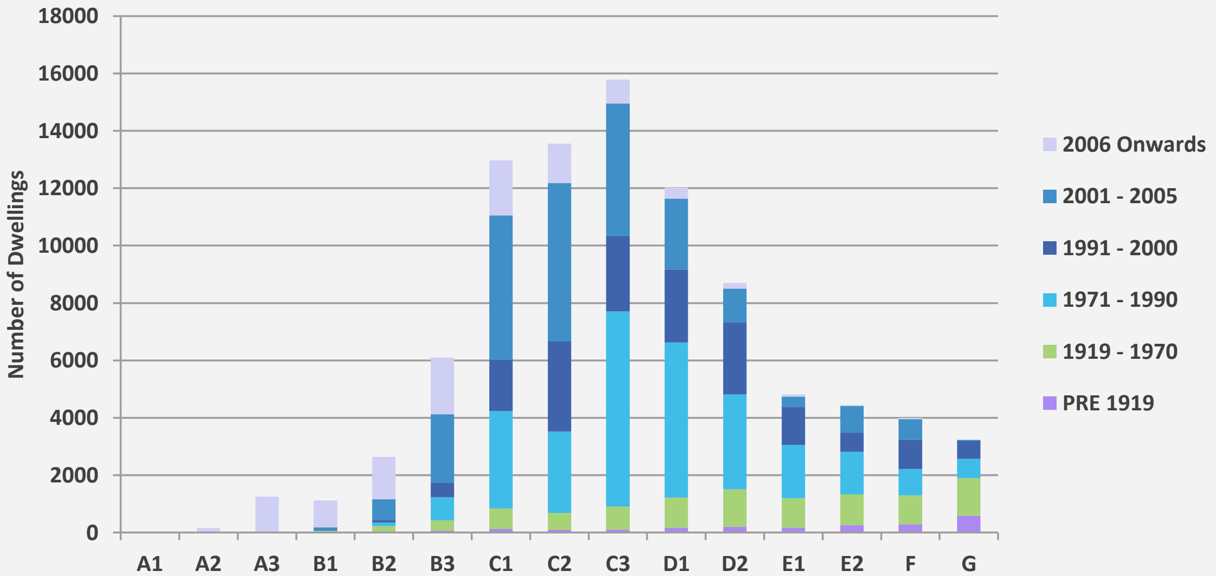

Figure 6 : Building Energy Ratings for all Fingal Households per Construction Period

These results help to visualise the current state of energy use in Fingal and inform the local authority when creating energy strategies for the region. The following chapter outlines the background methodologies and results of the Spatial Energy Demand Analysis, which places this energy consumption within a spatial context.

Residential Sector Energy

Methodology

Two main datasets which provide high levels of accuracy and detail are used in order to estimate the energy use in each dwelling in Fingal; they are the National Census from the CSO and the National BER Research Tool from the SEAI. At the time of the last Census in 2011, there were 102,793 permanent private households in Fingal. Of these, 9,842 were considered to be vacant and as such, do not have energy consumption attributed. Due to an increase in housing demand, it is assumed that some of these may now be occupied. Additionally, preliminary results for the 2016 Census announced an increase in the Fingal housing stock compared with 2011 figures. However, at the time that this report was written, the spatial distribution of these increases, both in new builds and filled vacancies, was not available and so, is not included in these calculations.

For the purpose of this report, the CSO compiled special tabulations presenting the number of dwellings by type and period built in each small area of Fingal. These attributes have a considerable effect on the theoretical energy demand as they can often define what building standards were in place during construction, level of insulation, exposed external wall area etc.

In line with data protection, the CSO is required to 'hide' data where the breakdown could possibly allow identification of individual households. In these cases, the CSO gave a figure of '<3' where the number of households in a breakdown category was either 1 or 2. In calculating the housing stock, each '<3' was replaced with '1', and so the energy use will be underestimated rather than overestimated. It is better to underestimate the demand, as, for example, for a group heating scheme to be feasible, the area will need to have a high heat density, and so an underestimate of heat demand is better. Also, the number of instances of '<3' were few, and replacing with '1' means that only 2,034 dwellings are unaccounted for throughout Fingal, which is 2.2% of the total. The total number of dwellings used for calculations is therefore 90,917.

In order to attach energy data to the housing breakdown, the National BER Research Tool database[11] from the SEAI was used to find an average energy profile of each housing type and housing age in each area within Fingal. The BERs only assess the energy requirements of the building itself and do not take into account electricity used for various appliances, therefore additional electricity use associated with appliances has been applied based on figures from the SEAI's Energy in the Residential Sector 2013 report (SEAI, 2013 (b)).

The BER dataset has been broken down into three Fingal postcodes, four housing types (detached, semi-detached, terraced and apartments), and seven building periods, with periods chosen to match those grouped by the CSO. There were over 53,000 BERs analysed and 84 subsets of data created to represent the variety of housing types, ages and locations. These profiles where then applied to the CSO housing data breakdown.

The representation of BERs in each postcode area is shown in Table 2.

Postcode	Number of SA's	Number of Dwellings	Number of BERs	% Represent-ed
Dublin 13	81	7,591	5,170	68%
Dublin 15	297	28,343	12,389	44%
Co. Dublin	560	54,983	36,158	66%
Total	938	90,917	53,717	59%

Table 2 : Representation of BERs in Each Postcode Area

Overall there is a 59% representation of BERs to total dwellings in Fingal. However, all postcodes in Fingal overlap into other regional authorities, and so there is a higher representation of BERs. This is an unavoidable consequence of the difference in postcode and local authority boundaries, but should not hinder the accuracy in energy estimates as a household will not use more or less energy because it is on one side or another of a regional boundary. Additionally, a higher number of BERs analysed should provide a more refined average.

As previously described in the introduction, the energy demand is primarily presented in a grid format. However, all maps with information calculated "per household"(including Figures 6, 8, 9, 10 and 11) will be visually presented through the spatial distribution of small areas.

[11] The BER database is constantly updated, and so it is important to state that for this project, the database was accessed on the 30th of July, 2016

Results

BER Analysis

From the comprehensive datasets available, it is possible to draw many conclusions about the residential energy demand in Fingal. Based on all documented BER data, BERs have been generated for every dwelling. This is represented in Figure 9, showing the average BER for each Small Area. The highest average BER is a B, which is located near Ridgewood, Swords and includes the new apartment complexes at Cedar Place, as seen in Figure 7.

As previously mentioned, the most common rating among dwellings in Fingal is C, totalling 42% of the housing stock. However, when calculating the average BER for each SA, there are 595 SAs in Fingal with an average BER of D, compared with only 332 SAs with a BER of C. This is particularly evident in Figure 10, as the map is heavily dominated by yellow. This occurs for two reasons. Firstly, the B and C rated homes tend to be located in SAs with more households in newer, more densely developed areas, often featuring apartment developments. This means that B and C rated buildings are concentrated closely together dominating certain SAs while not achieving majority in others. Areas featuring a high average C rating are predominantly the newer built areas surrounding Blanchardstown, Clonsilla, Castleknock and Swords. Secondly, there are more E, F and G rated homes than A and B, which lowers the average BER rating in each SA.

There are few SAs in Fingal averaging below a BER of D. Among these include the area depicted in Figure 8, situated adjacent to the Swords Library and Rathbeale Road. This consists of 140 occupied households, the vast majority of which are semi-detached and built between 1971 and 1990.

Another similarly poorly rated area is in the Electoral District of Donabate, including the Portrane Demesne, illustrated in Figure 9. Of the 63 occupied households in this SA, the vast majority were built either before 1919, or between 1919 and 1970. These areas should be prioritised for energy efficiency measures or included in schemes such as the SEAI's Better Energy Homes.

The effect that construction year has on the BER and energy demand of buildings is evident as the adjacent SAs in the newer built suburbs of Donabate have an average BER of C. These dwellings are also predominantly semi-detached but are almost entirely built post 2001.

Figure 7 : Average B and C ratings (dark and light green respectively) in areas around the newly developed Ridgewood, Swords.

Figure 8 : Average E rating (Orange) in suburban area near Rathbeale Road

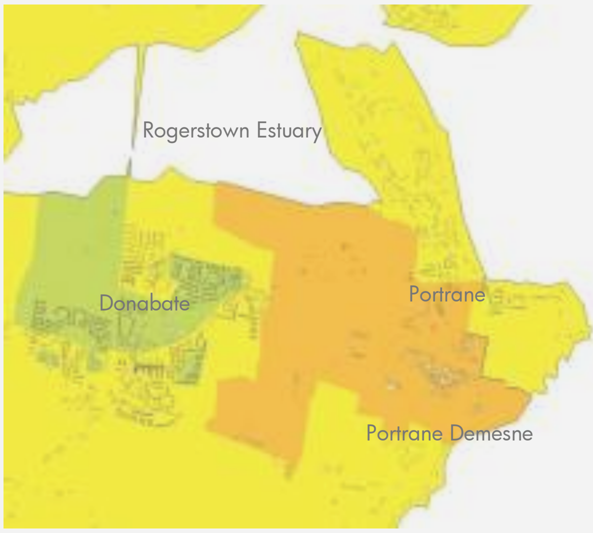

Figure 9 : Average C rating (Green) at newly developed Donabate suburbs and Average E rating (Orange) at Portrane Demesne

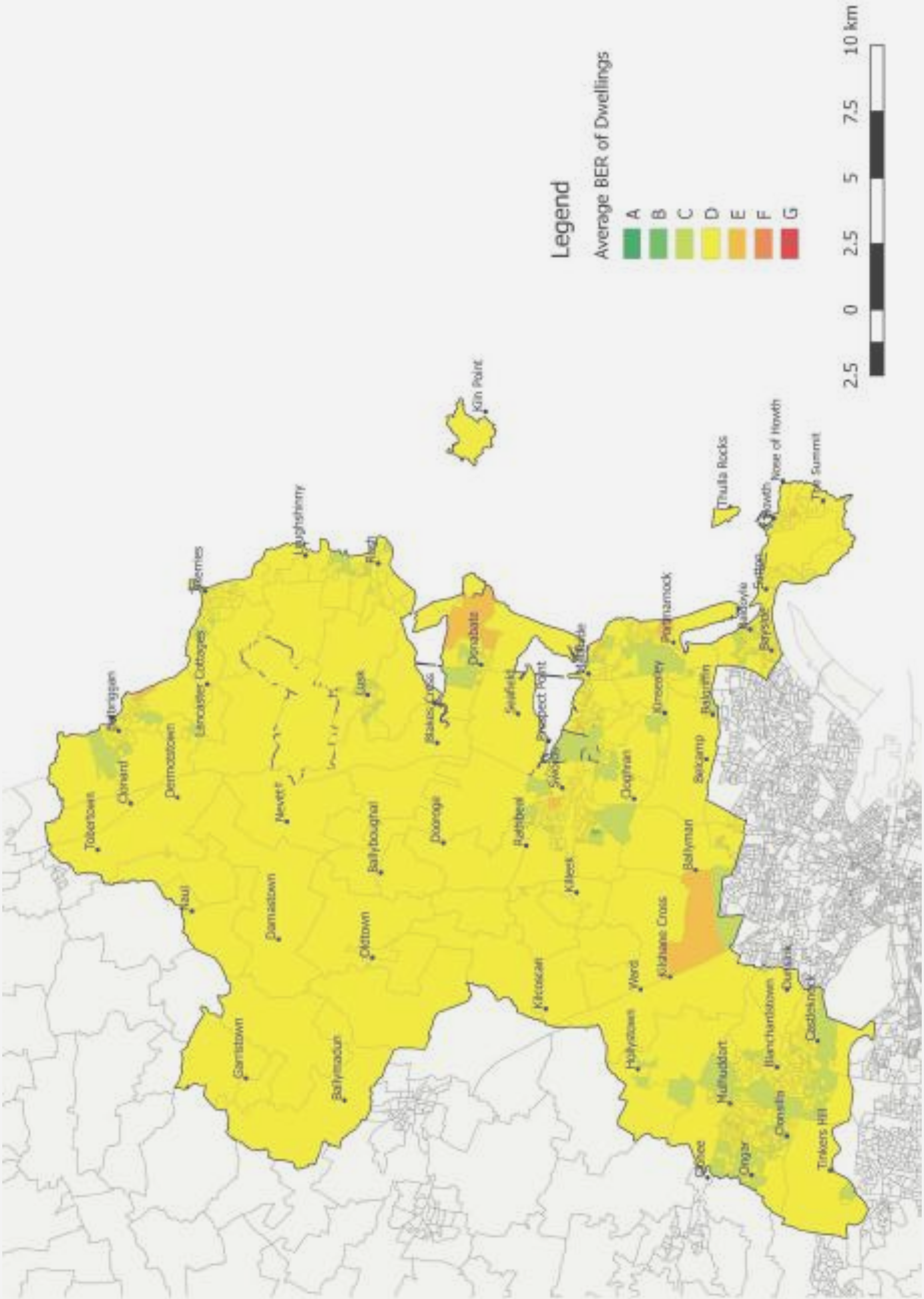

Figure 10 : Average BER of All Dwellings in Each Small Area

The results of the BER analysis show that, while better building regulations for new builds are effectively reducing the energy demand in new developments, the rest of Fingal's dwellings are becoming older and less efficient. To really reduce energy use in this area, these households should be retrofitted with sustainable solutions.

Energy Use per Household

The next map, Figure 12, shows the average energy use per dwelling in megawatt-hours (MWh). The green and dark green areas have low energy use per dwelling, with the light yellow band representing the average energy use in Fingal. This is between approximately 22 and 28 MWh per year. In comparison, the national average energy use per household is around 20 MWh (SEAI, 2013 (b)), meaning Fingal is slightly above the national average.

The areas that performed well in the average BER calculations predictably have a lower energy use per dwelling, as mapped in Figure 12. Dwellings in the more densely populated areas such as Blanchardstown, Swords and Donabate tend to have smaller sized dwellings, often comprising of apartments or semi detached developments, and therefore require less energy to maintain thermal comfort. This correlation between floor area and energy use can be seen in comparing Figure 12 and Figure 13. It can be seen that the built-up and more densely populated areas of Fingal tend to have smaller internal dwelling areas. However, it also highlights areas which may not have very large floor areas but still rank high in energy usage, and vice versa for areas with large floor areas and low energy usage.

In Figure 12, the areas of orange and red have above average use per dwelling, and in some cases, over double the average energy use of a dwelling in the dark green areas. While this map appears to be dominated by high energy dwellings, these areas are predominantly rural and sparsely populated. The SAs coded in red account for 58% of the land area, yet only 7% of all households in Fingal. Land is not as valuable or sought after in these rural areas as it would be in the urban areas of Blanchardstown or Swords and so, houses are often larger and detached. These dwellings also tend to be of an older construction period, the housing stock accumulated over many decades rather than being built in the early 2000's construction boom.

Energy Costs per Household

The estimated energy costs per household are mapped in Figure 14. Many areas shown here with higher than average energy costs overlap with areas shown in Figure 12 with high energy use per household, but there are other areas which have high costs, not due to the size of the dwelling, but due to the fuel used for water and space heating, and efficiencies of heating systems. The main fuel used for household space heating in Fingal is natural gas, as can be seen in Figure 11, but many apartments are electrically heated using storage heating units. Additionally, some households have oil boilers due to distance from the gas grid. Many households also have electric showers or electric immersions for hot water.

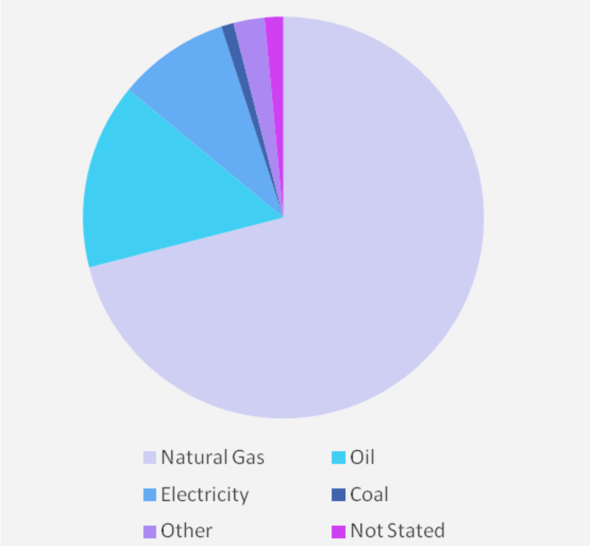

Figure 11 : Heating Fuel Use in Fingal

The fuel prices used in this analysis are based on SEAI's Domestic Fuel Cost Comparisons (April 2015), and electricity and gas prices per kWh have been applied to each household according to the usage price bands. Domestic electricity rates in Ireland are the second highest in Europe, and third highest when all taxes and levies are included, just behind Denmark and Germany (S1, 2015) (Eurostat, 2016). Oil used to be more expensive than natural gas, but the price has dropped recently and now oil is close to the same cost per kWh as gas.

The areas in dark green in Figure 14 have very high energy costs and are mainly located in more rural areas with large housing units. The SA with the highest estimated energy costs, at €4,340 per household, is situated in Howth in Dublin 13 and consists almost entirely of detached houses built before 1970, half of which were built before 1919.

The lighter green areas have lower costs, but are still relatively high per household, with many smaller households paying over €2,000 per year for energy. These costs can make up a large part of a household's annual income, and can cause households to be without heat in the winter season. Again, it is not surprising that the areas coloured light yellow, indicating low energy costs, are those which also feature the smallest floor areas and lowest energy usages per dwelling.

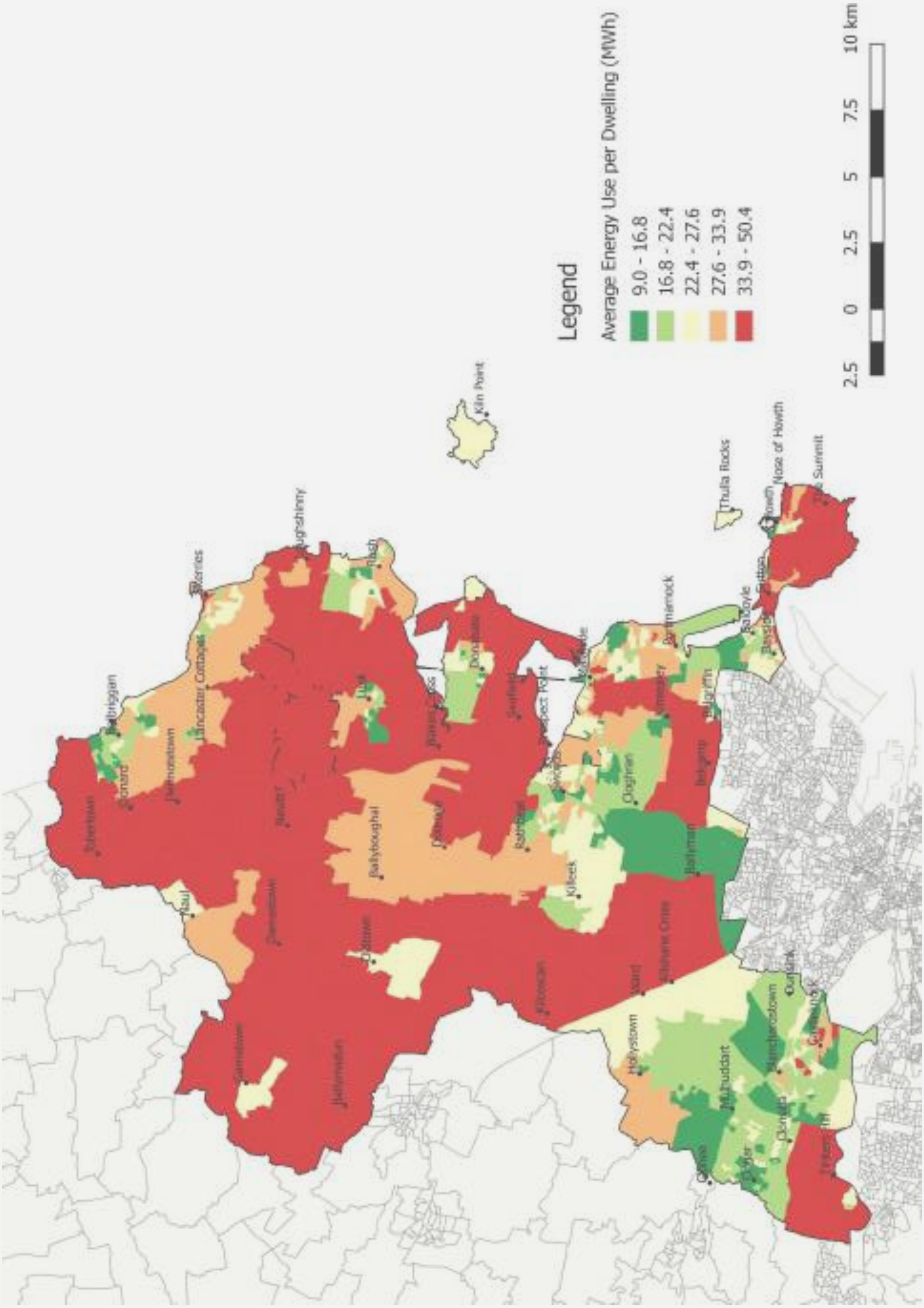

Figure 12 : Average Annual Energy Use per Dwelling in Each Small Area

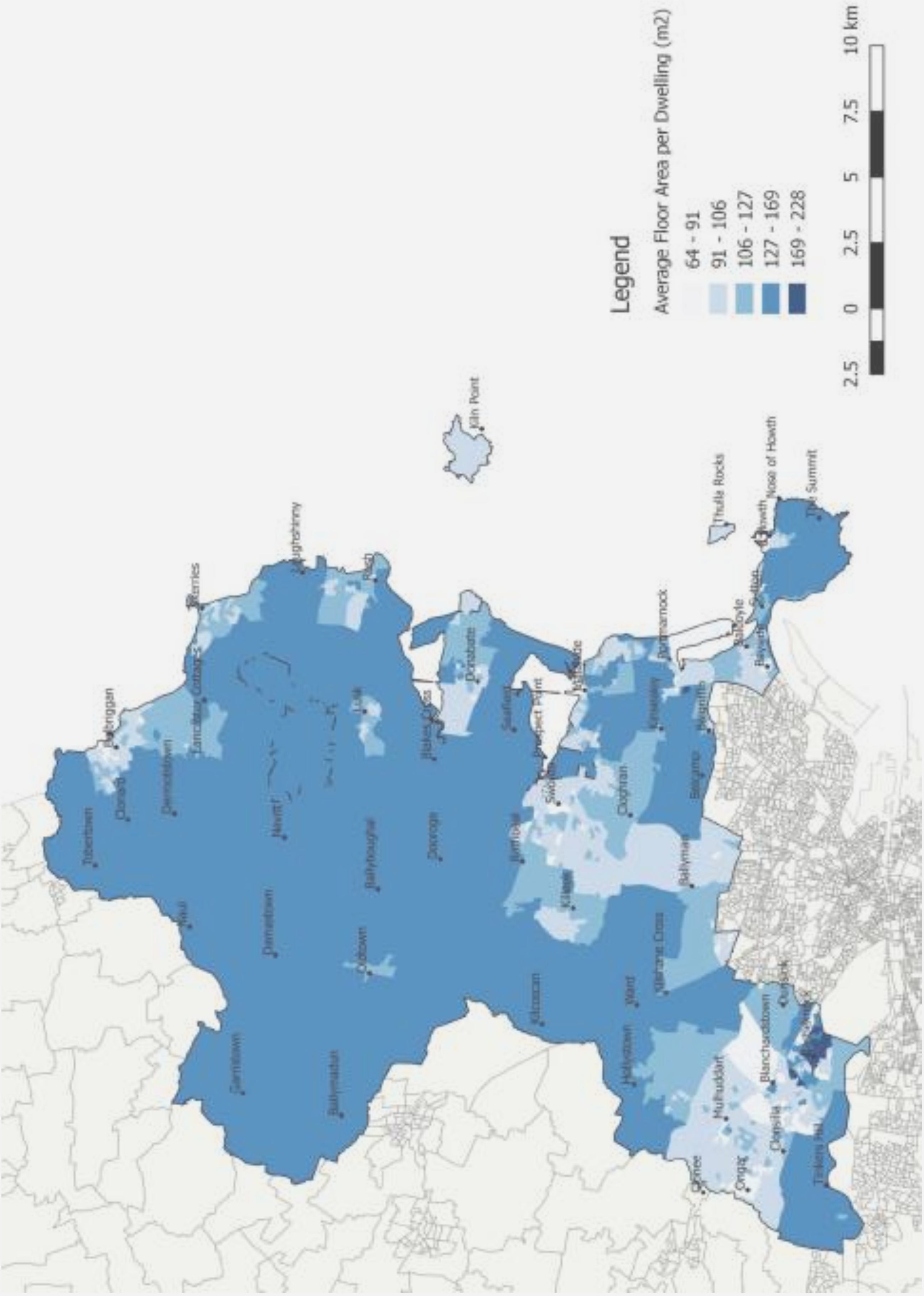

Figure 13 : Average Floor Area of Dwellings in Each Small Area

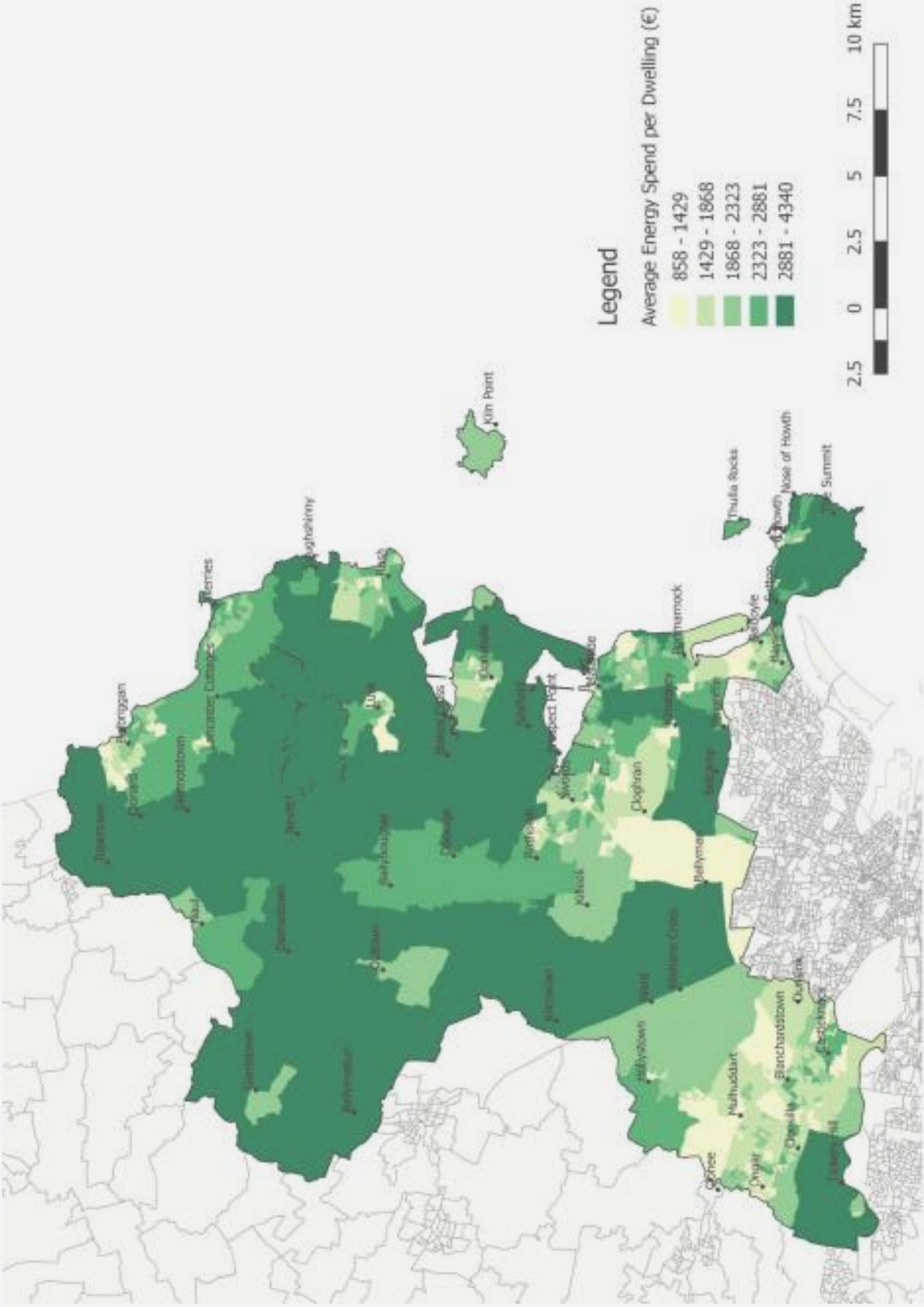

Figure 14 : Average Annual Energy Costs per Dwelling in Each Small Area

Areas with High Risk of Energy Poverty

There is much difficulty in defining energy poverty and how to target those worst affected, as outlined in the then Department of Communications, Energy and Natural Resources' (DCENR) consultation paper on a new affordable energy strategy (DCENR, January 2015). Someone suffering from what is termed energy poverty is said to be unable to heat or power their home to an adequate degree. Three factors which influence this are: household income, cost of energy, and energy efficiency of the home. Without knowing the income levels in each small area to compare with estimated costs from this analysis, the best way to try to map areas most at risk of energy poverty is to overlap the known data and compare the energy efficiency levels of homes with levels of unemployment in each small area[12].

A map showing the small areas in Fingal which are most at risk of energy poverty, based on high energy costs, resulting from a low BER, and high levels of people who are unemployed or unable to work, are shown in yellow in Figure 15.

The DCENR defines energy poverty as spending above 10% of annual disposable income on energy (DCENR, 2014). In areas where there is unemployment above 30%, there is a sizeable proportion of households who can be assumed to be on a social welfare income. An average social income per household is said to be €327 per week, equating to roughly €17,000 per annum (ESRI, 2011). In this instance, annual energy spends of over €1,700 would push these households into energy poverty. Thus, Figure 14 identifies 18 small areas that can be said to be at risk of energy poverty due to estimated energy costs and unemployment levels. This method of targeting takes into account ability to pay for energy and energy efficiency ratings.

Areas at risk can be further broken down to target those most in need first, and the top ten areas most at risk based on energy efficiency of dwellings, ability to pay for energy and estimated costs of energy per dwelling, can be seen in Table 3. There are 901 households in these most at risk areas in total, and it is recommended that further analysis is carried out on these households in order to find the best-fit solution to reducing the energy demand and energy costs to these households, and include this housing in future efficiency retrofit schemes.

Electoral District	Small Area Number	No. of Dwellings	% Unemployed	BER	€ Cost/HH
Donabate	267065010	63	51%	E	2976
Blanchardstown-Corduff	267030006	118	31%	C	1933
Blanchardstown-Blakestown	267028004/02	91	42%	C	1894
Swords-Lissenhall	267133002	89	33%	D	1835
Balbriggan Rural	267002045	89	32%	D	1828
Blanchardstown-Mulhuddart	267032009	95	34%	D	1793
Blanchardstown-Tyrrelstown	267034005	88	31%	D	1792
Blanchardstown-Coolmine	267029017	100	35%	C	1779
Blanchardstown-Corduff	267030007	91	31%	D	1746
Balbriggan Rural	267002046	77	32%	D	1740

Table 3 : SAs at Highest Risk of Energy Poverty

[12] The data for unemployed or unable to work comes from the 2011 Census, and there is no more recent data available at a small area level. The 2016 Census is due to be published next year in 2017, and so these figures can then be updated and better reflect the upturn in the economy since 2011.

Total Residential Sector Energy Demand

The total annual energy demand, total annual electricity demand and heat demand density of the residential sector are shown in Figure 16, Figure 17 and Figure 18. The total energy demand map shows the areas in Fingal most responsible for the energy use of the residential sector. These areas should be targeted for energy efficiency awareness campaigns and education on renewable energy solutions for households. The energy demand is also broken down into electricity demand and fossil fuel demand to show areas which can be targeted for different renewable energy solutions.

Areas with high electricity usage can be prioritised for rooftop PV installations, or in some suitable cases micro-hydro or micro-wind power, to offset some of their electricity usage. Households with electrical heating systems such as storage heating should consider replacing old systems with new, high efficiency smart electricity storage systems or where practical, replacing with a wet system which can incorporate heat pumps, solar thermal and geothermal heat sources. Many apartment complexes were fitted with all-electric systems due to low cost and ease of installation. A group scheme with a central high efficiency CHP plant in such complexes can supply electricity and heat to the building and reduce overall fuel usage and costs. The biggest problem with many apartments, bed-sits and flats in the county is they are rented, and the tenants cannot make the big changes required to reduce their energy costs, and there are no incentives for landlords to upgrade the energy efficiency of their properties, especially in the current market where there is a lack of rental properties available.

Areas with high fossil fuel usage cause the highest amount of local air pollution, particularly those which burn solid fuels such as coal and peat. From census data, the highest percentage share of coal or peat used as a main heating fuel in any small area is around 10%, which is relatively low in comparison to rural areas which do not have access to the gas grid. Open fires and stoves are often used in dwellings as secondary heat sources and so it is likely the number of dwellings which use solid fuels is underestimated when looking at main heating fuel only. With the local pollution and CO_2 emissions caused by burning coal and peat, and the very low efficiencies of open fires (around 20%), it is important to ensure households switch to sustainable and cleaner forms of fuel such as wood, wood chips and wood pellets, and install highly efficient stoves in place of open fires. It is relatively cheap to install a wood fuel stove, and this not only reduces negative effects on the environment and health, but also saves money due to much higher efficiencies of up to 90%.

The majority of the fossil fuel used in dwellings in Fingal is natural gas and, in a smaller share, home heating oil. Areas which have high levels of oil and gas used for hot water and space heating requirements should be encouraged to find renewable or sustainable alternatives. For individual building based systems, there are many proven and well established technologies which can greatly reduce a household's reliance on fossil fuels; these include air, water and ground source heat pumps, solar thermal panels, heat recovery ventilation systems, and biomass-fuelled boilers or stoves. These solutions should be supported and included in home energy improvement grant schemes. For suitability of areas and households for each renewable energy solution, see the section in this report on renewable resources (p.59).

District heating is a shared heating system with a central heating plant which feeds heat to each household on the system. As discussed in the introduction of this report, DH should be prioritised in areas of sufficiently high heat density. DH systems are likely to be more economically feasible if there are large commercial or industrial customers also on the system, due to high heat demand over long periods year round, but there are also many successful stand-alone residential schemes in operation.

There are a number of areas, found around the Swords area, with high residential heat demand densities of over 250 TJ/km^2. It may be more economically advantageous for groups of housing with heating systems which need to be replaced and in areas of high heat demand density to consider a cooperative DH scheme. DH can be expensive to retrofit due to ground works required for pipelines, and so DH is particularly suited to new housing developments or housing close to existing or planned DH schemes. DH feasibility will be further analysed later in this section when commercial and industrial energy use is combined with residential energy and the resulting total heat density is mapped.

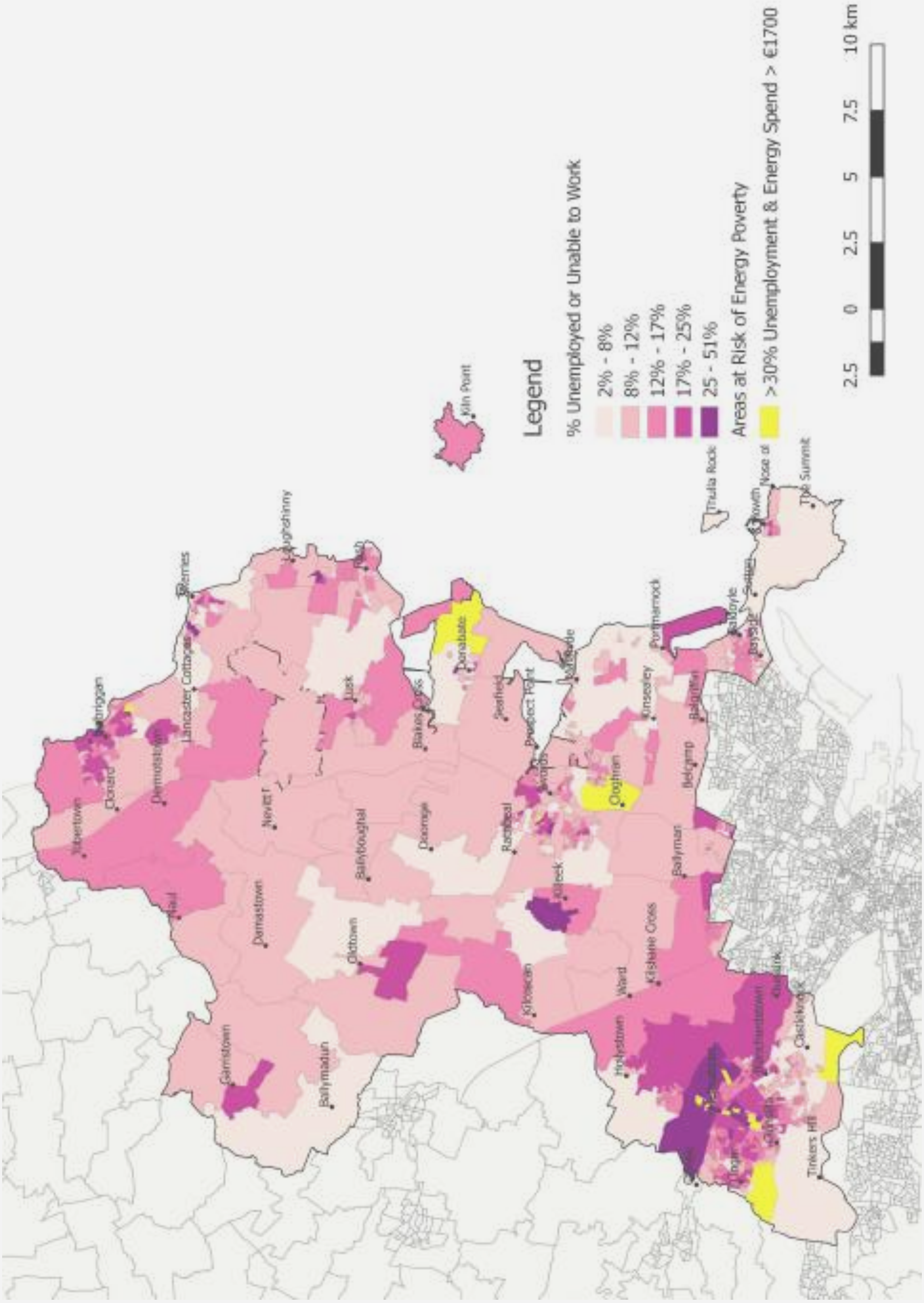

Figure 15 : Areas Most at Risk of Energy Poverty

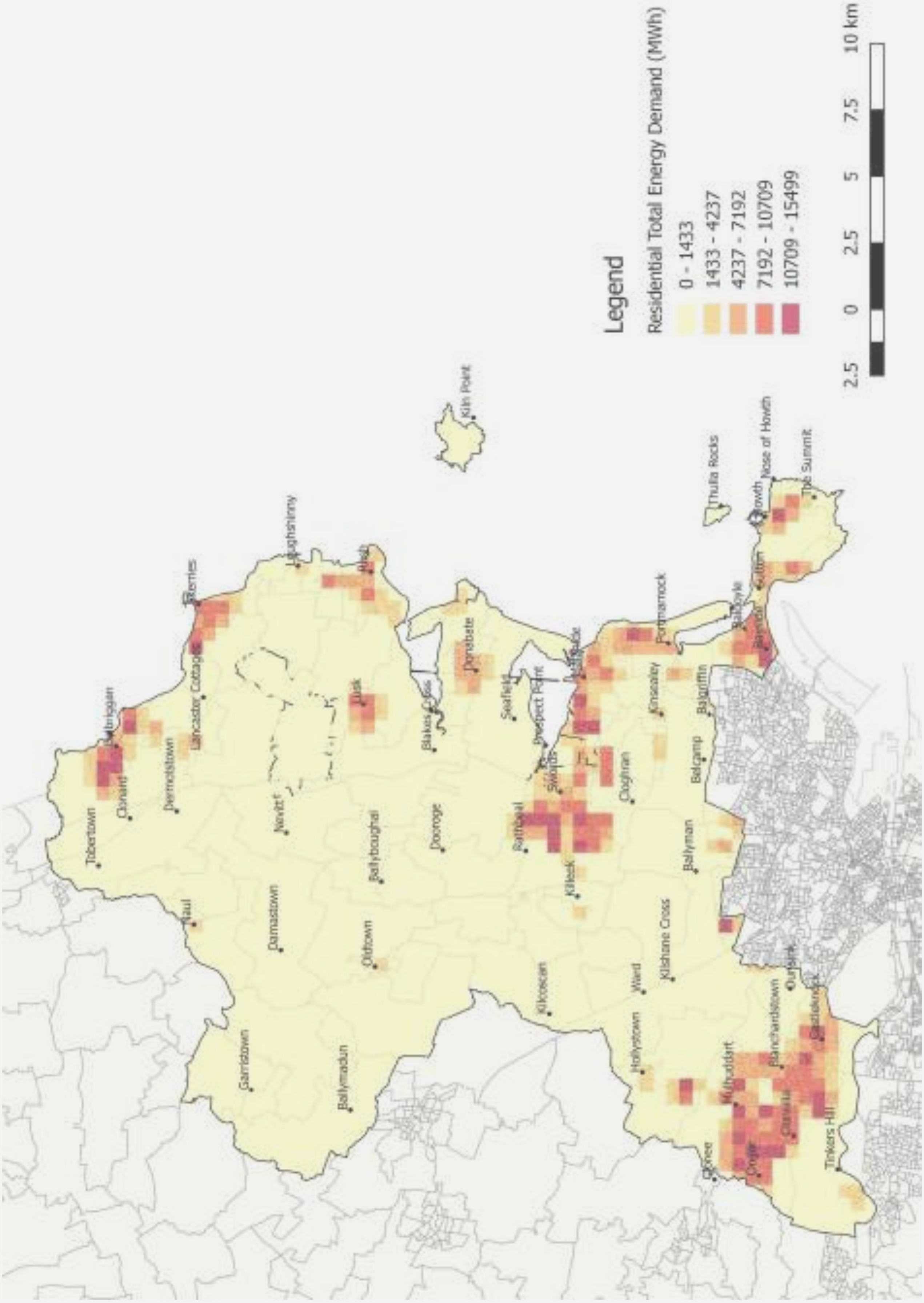

Figure 16 : Total Annual Residential Energy Demand (MWh)

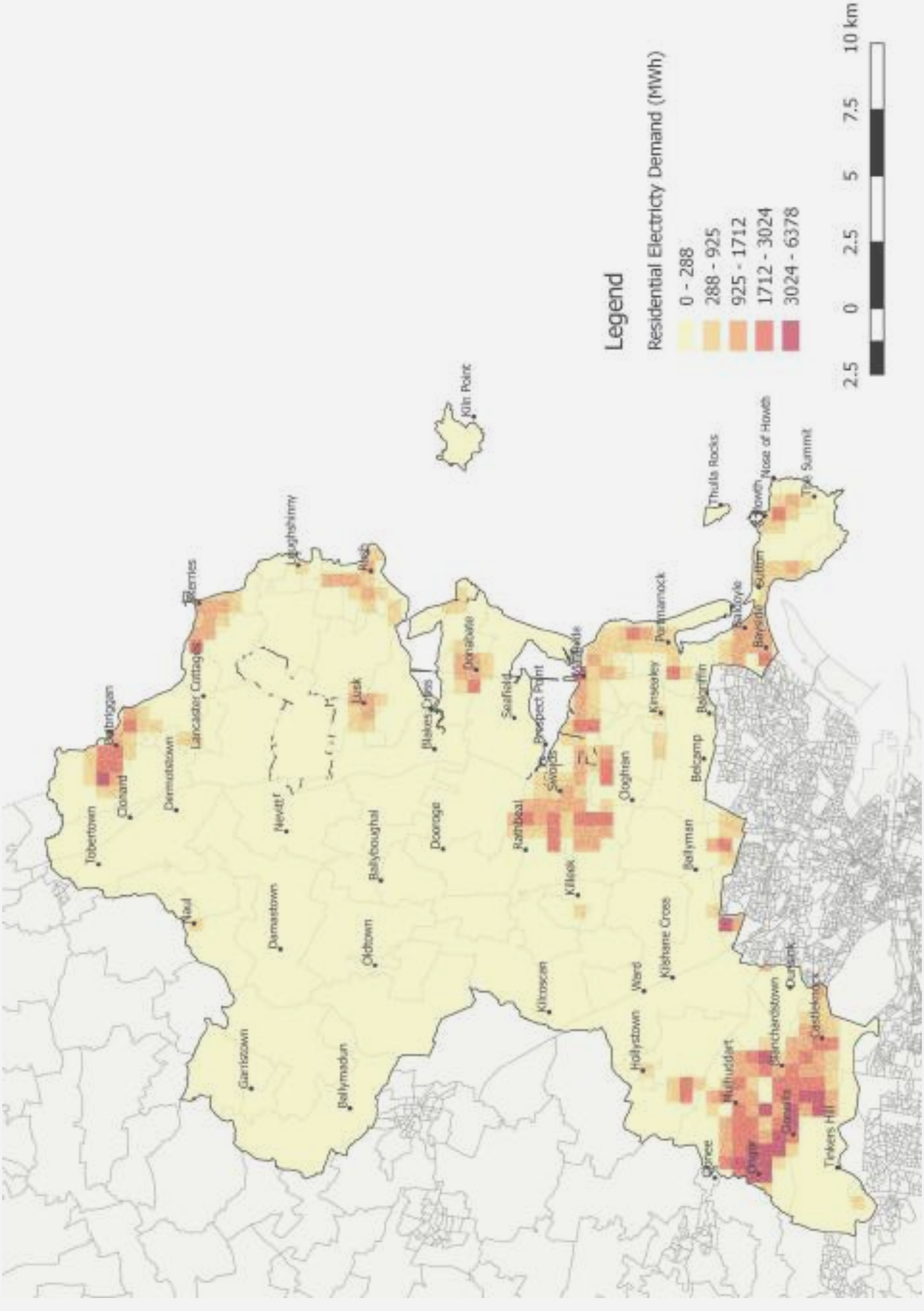

Figure 17 : Total Annual Residential Electricity Demand (MWh)

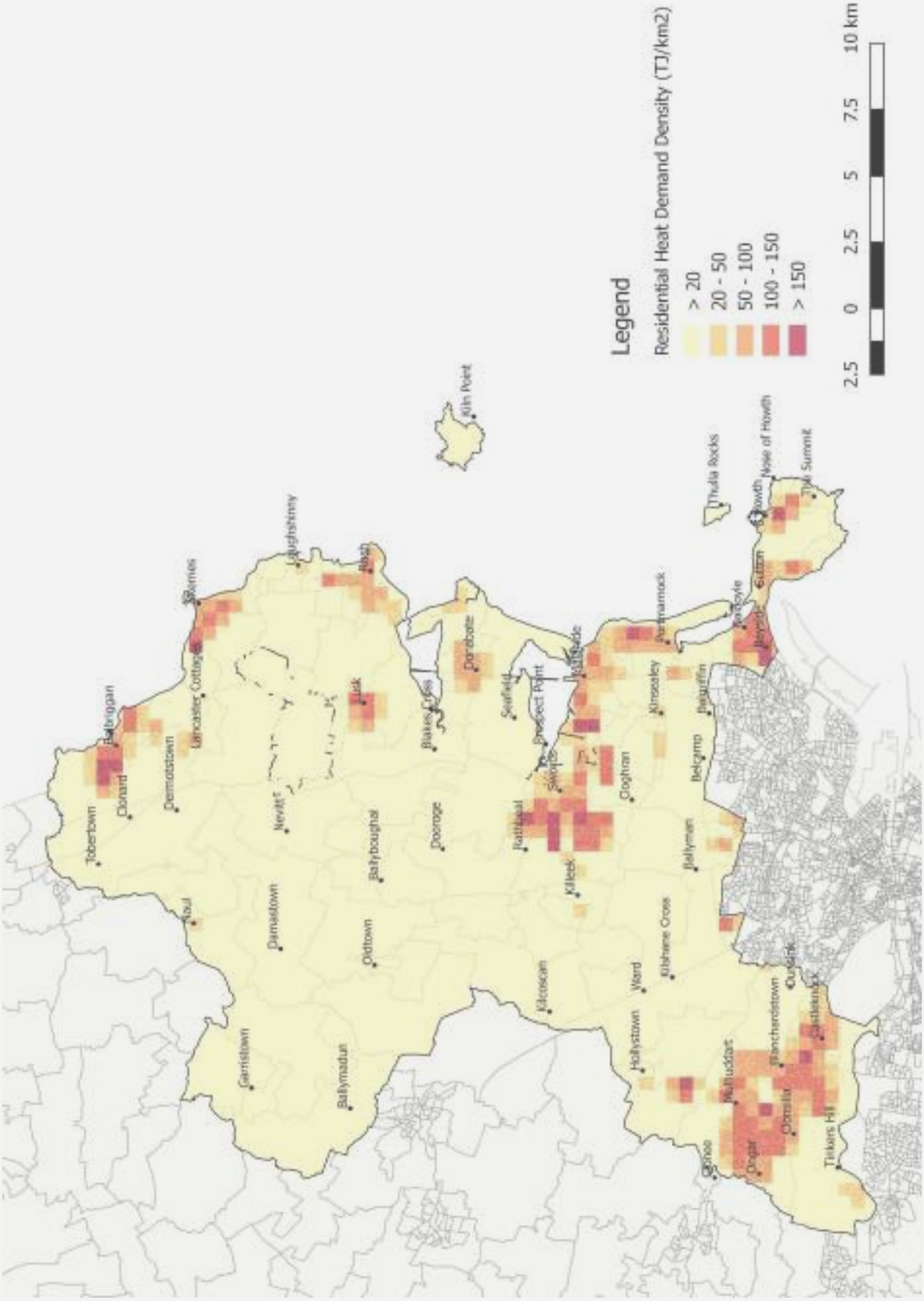

Figure 18 : Residential Heat Demand Density (TJ/km^2)

Commercial Sector Energy

Methodology

The commercial sector in Fingal (which includes services, manufacturing and industrial activities) has very little real metered energy data publicly available for research, and it is therefore difficult to estimate the energy demand in every building in the county used for such activities. The most well established source of energy data for the commercial sector comes from the UK's Chartered Institution of Building Services Engineers' (CIBSE) technical documents. This data is widely used in Ireland for modelling commercial sector energy consumption, and is used for the comparison benchmarking in Display Energy Certificates (DECs) in Ireland. CIBSE provides energy benchmarks which are divided into annual electricity use per meter squared floor area and annual fossil fuel use per meter squared floor area for numerous service and industrial activity types. The benchmarks used in this study come from CIBSE Guide F: Energy Efficiency in Buildings 2012, and CIBSE Energy Benchmarks TM46: 2008 (CIBSE, 2012) (CIBSE, 2008).

To match these benchmarks to each commercial activity in Fingal, the Valuation Office (VO) provided a list of 6055[13] commercial properties within the county boundaries, which included the business activity type, i.e. pub, hairdresser, office, etc., the floor area, and the latitude and longitude coordinates of each listing. This allowed an estimate of energy use for each commercial building based on CIBSE benchmarks applied using floor area and business type, and each building can be mapped and linked to a small area polygon. Some properties listed by the VO contained errors in coordinates and were missing essential data, and after these had been filtered and discarded, the 5,993 properties remaining have been analysed and mapped.

The floor area measurement used by the VO for different building uses, found in the VO's Code of Measuring Practice for Rating Purposes 2009, often differs to the floor areas used to measure energy use in the CIBSE guides. In these cases, a correction factor has been applied where applicable, for example to convert gross floor area to sales floor area, etc.

Estimating the costs of energy associated with commercial energy use is difficult as the CIBSE energy benchmarks only breakdown the energy use into electricity and fossil fuel consumption. The only available source of information on fossil fuel types used in this sector is from national level studies, which give a breakdown of fuels used in the industrial and services sectors, and so this is used to give an estimate of fossil fuel types consumed. Using this data will have the unwanted effect of pricing more energy use according to oil prices rather than gas prices, as there will be higher use of gas in the Fingal area compared to national usage due to the penetration of the gas grid in Dublin. Therefore, costs allocated to fossil fuel uses are likely to be slightly overestimated for this sector. The costs used are from the latest SEAI *'Commercial/Industrial Fuels: Comparison of Energy Costs'*, which includes all taxes and standing charges, and costs are allocated to each building taking account of the price bands used in gas and electricity pricing.

Results

The map shown in Figure 22 shows the location and energy use of each commercial property in Fingal. Each location has been mapped individually to show exactly where in each small area the business is located, and shows clusters which may overlap into other small areas. Each location is marked with a coloured circle, with colour representing annual energy usage in MWh, the orange and red circles having higher than average energy use.

A zoomed-in section of the centre of Swords can be seen in Figure 19, and the individual business locations can be identified. In this figure, the majority of activity is seen to be centred along Main Street and North Street, with many SMEs located along this route. Other areas with significant amounts of concentrated commercial activity include Swords, Blanchardstown, Malahide and Skerries.

On the immediate outskirts of these urban hubs, the activity tends to be more industrial, with larger building footprints and higher energy demands. Large scale industrial estates and business parks such as Baldoyle Industrial Estate, Ballycoolin Industrial Estate and Damastown Industrial Estate are situated outside of the commercial and residential hubs, therefore spatially dispersing the energy demand in Fingal. The highest energy users are pharmaceutical factories, meat factories and food preparation facilities.

[13] It is important to note that it is not guaranteed that this is an exhaustive list of businesses and there may be some businesses unaccounted for.

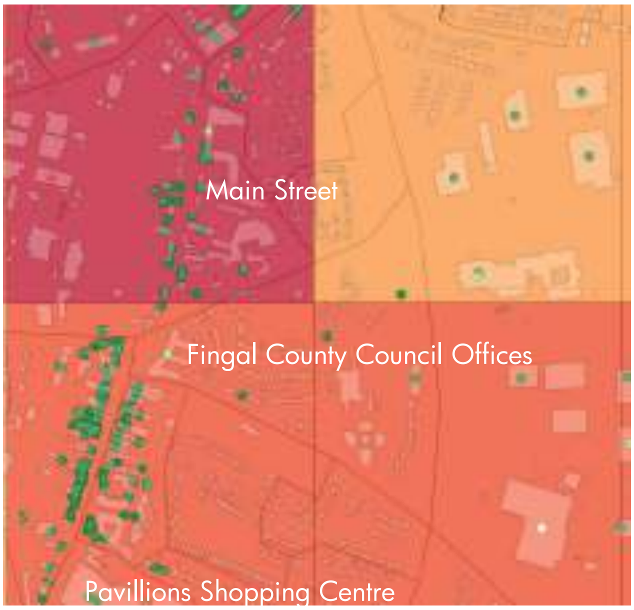

Figure 19 : Dense concentration of commercial properties along the Ward River, Swords

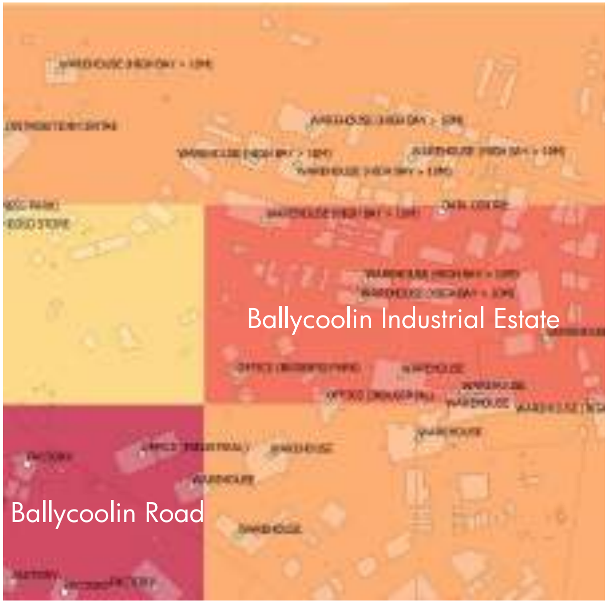

Figure 20 : Warehouses and industrial use properties at Ballycoolin Industrial Park, near Clonee.

Due to these manufacturing and industrial type activities, the clusters of energy use outside of the urban hubs have some of the highest energy use in the local authority area. The areas with the highest commercial energy use, above approximately 20 GWh annually, are shown in red in Figure 23. Businesses in these areas should look at cooperative ways to reduce energy reduction through shared energy systems and infrastructure, shared investments in medium scale renewable installations, and recycling of waste heat. Many of the industrial estates, such as Damastown and Ballycoolin, depicted below in Figure 21, have buildings with large roof spaces and little over-shading issues which are ideal for commercial scale solar PV installations. These installations can greatly off-set a business's energy costs, as the panels will produce most energy during the day during business hours and will offset expensive daytime electricity rates. Commercial activities which produce waste heat have the opportunity to sell this heat to neighbouring businesses to meet heating requirements, thus increasing efficiency, reducing cooling requirements, and creating additional revenue.

Figure 21 : High energy demand and high volume of commercial activity within Damastown and Ballycoolin Industrial Estates

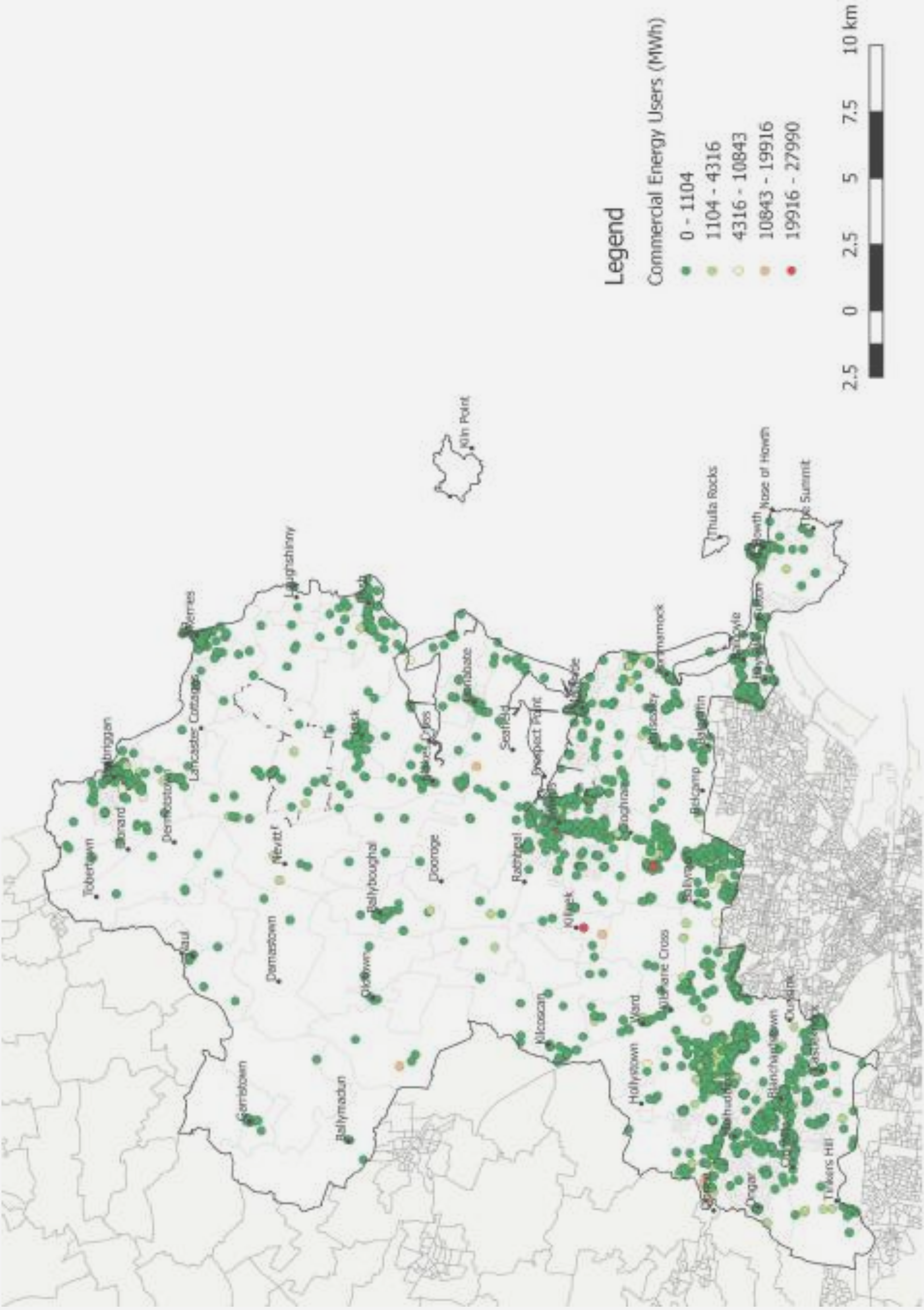

Figure 22 : Commercial Energy Users (MWh)

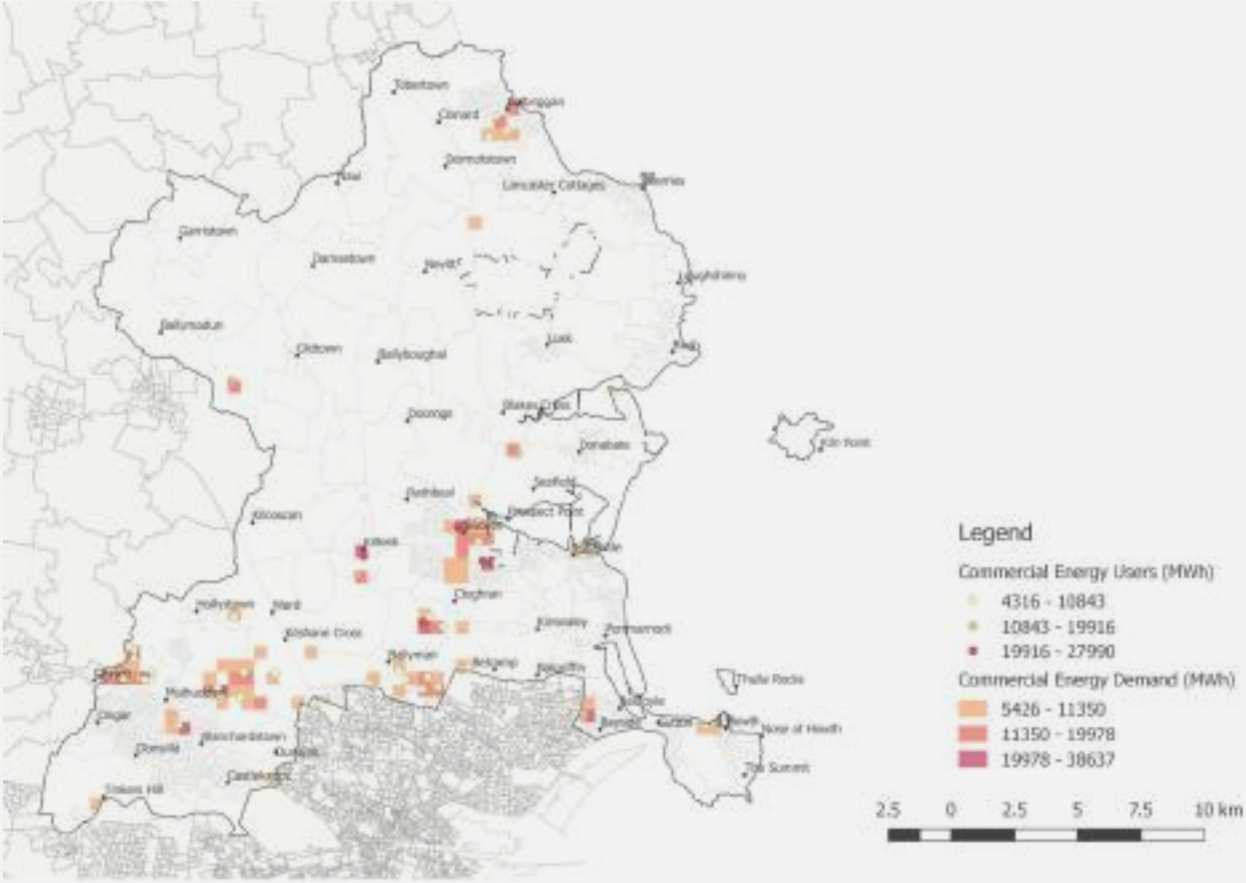

Figure 23 : Areas of Highest Annual Commercial Energy Use

Total Commercial Sector Energy Demand

The map in Figure 25 shows the total annual commercial energy usage over the entire county of Fingal. The areas highlighted which have high energy demands largely overlap with the clusters of commercial businesses seen in Figure 21. However, there are some outlying areas showing high demand based on one or two very large energy users, located away from any commercial or industrial hubs. For example, the area in light red near the Kileek area contains very little retail or other commercial properties, yet includes two large food preparation facilities. These are energy intensive facilities which drive up the commercial energy use in this area. Most other areas of medium to high energy demand are found in the small and concentrated urban hubs, such as Swords and Blanchardstown, or in industrial estates.

In the Ballycoolin area alone, this analysis includes 872 separate commercial facilities, with an annual energy demand of 198 GWh, accounting for over 14% of total commercial energy demand in Fingal. Damastown Industrial Park, situated close to Ballycoolin and shown in Figure 20, totals 162 GWh of energy demand, equating to almost 12% of the total commercial demand. Between Airways Business Park, Baldoyle Industrial Estate and Dublin Airport, this accounts for a further 14% of the total. These five industrial hubs in Fingal can be clearly identified in Figure 23, representing the majority of dark red and light red SAs. The property uses in these areas are predominantly factories, warehouses and food preparation facilities. The high energy demand of these businesses and proximity to each other within these industrial parks mean that they are in ideal positions to become energy "prosumers", whereby they actively produce as well as consume energy.

Ample roof space and high day time electricity use in production processes make these properties suitable for Photovoltaic (PV) installations to offset their own use. This is a common cost reduction strategy for many large commercial businesses in Europe, including Lidl, Aldi and IKEA. Additionally, many large companies have also employed wind power to supply their own demand. In Fingal, the considerable amount of sparsely populated rural land makes it suitable for wind turbine installations from a spatial planning perspective. There is a real opportunity for the businesses based here to create an energy group and work together to reduce their energy use and costs, and at the same time help the county to become more sustainable. Suitable areas will be identified in the renewable resources section of this report.

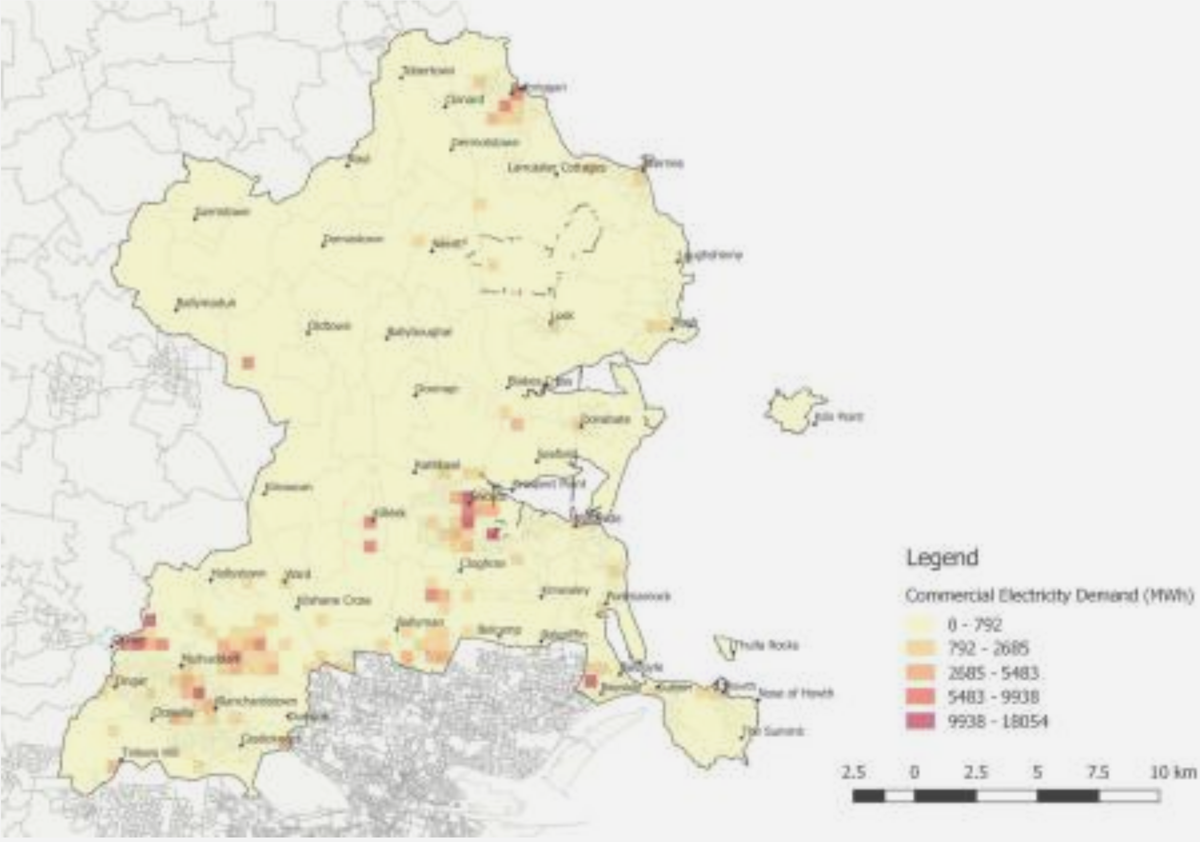

Figure 24 : Total Annual Commercial Electricity Demand (MWh)

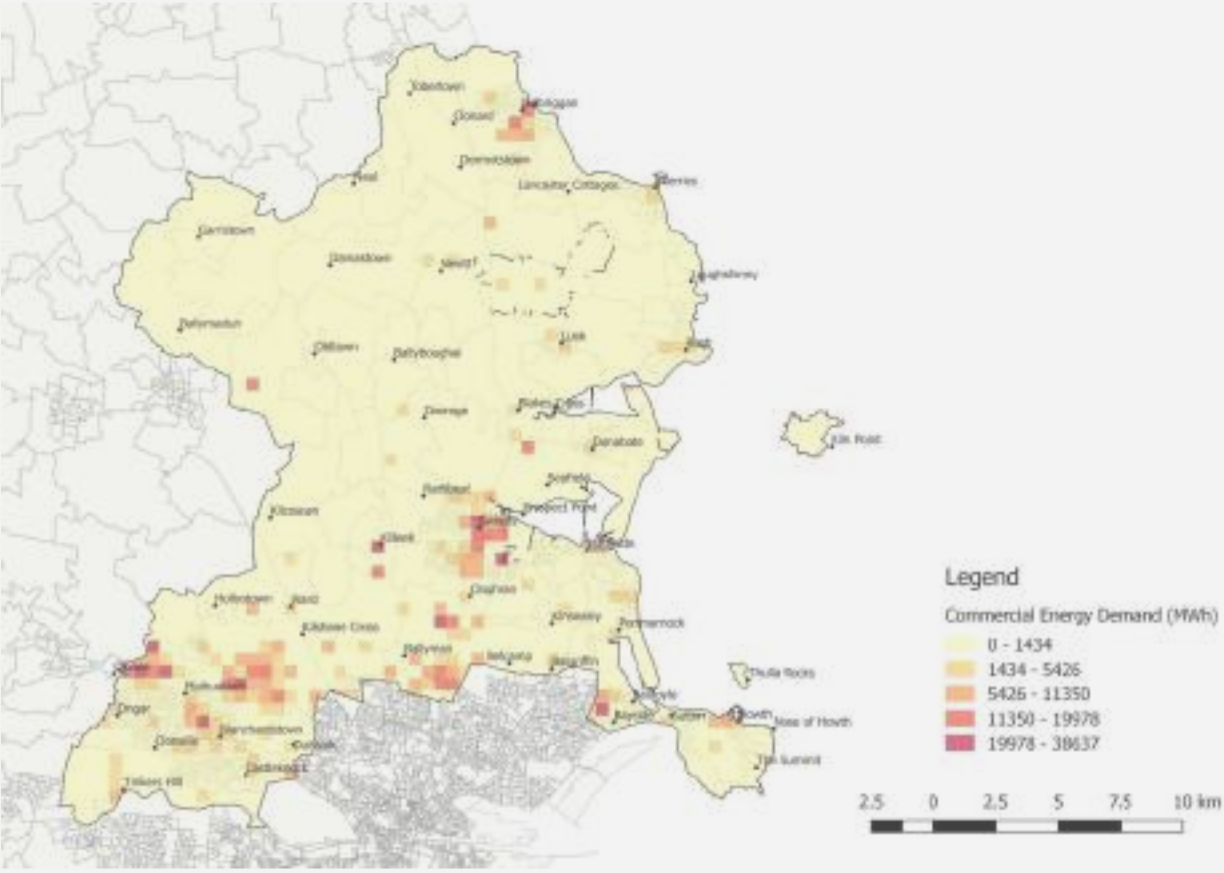

Figure 25 : Total Annual Commercial Energy Demand (MWh)

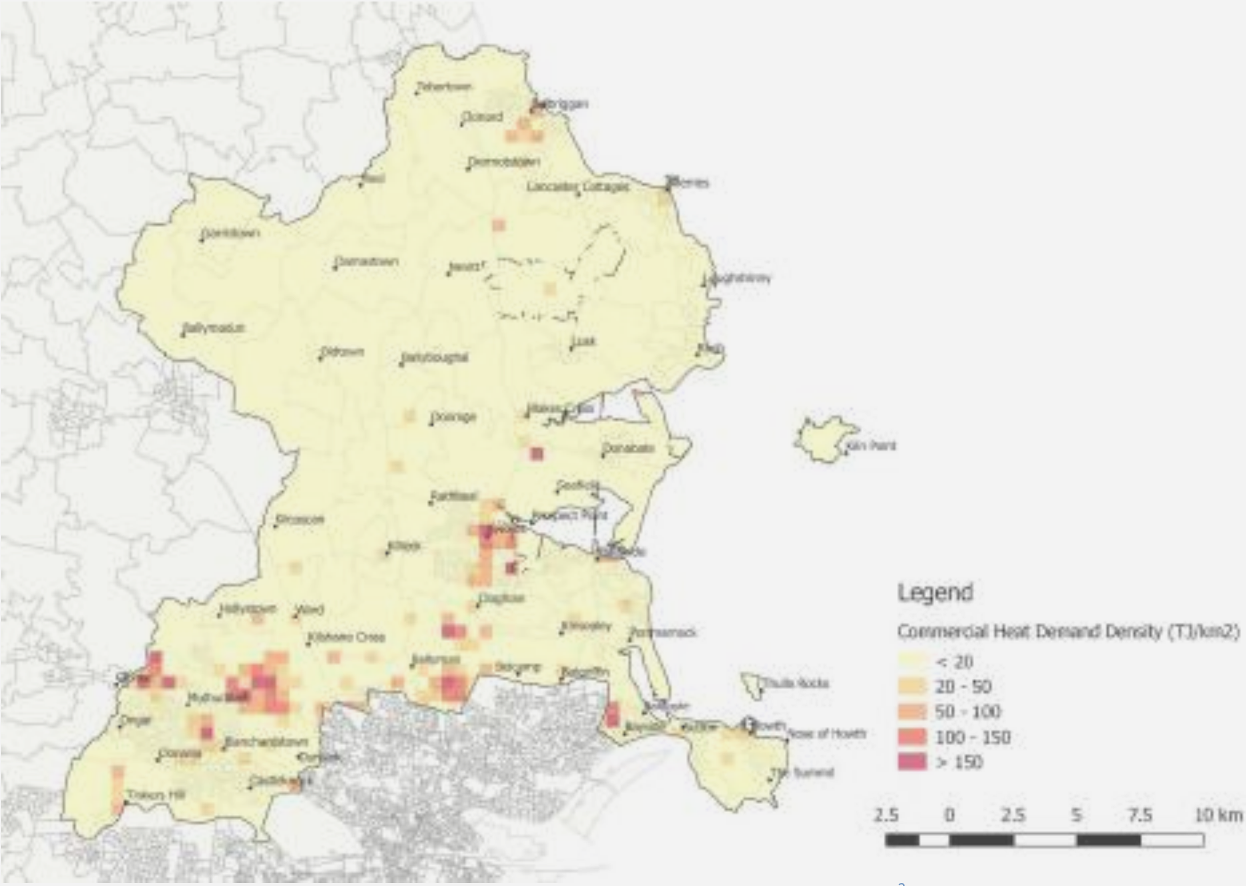

Figure 26 : Commercial Sector Heat Demand Density (TJ/km^2)

The electricity demand of the commercial sector is shown in Figure 25, which largely overlaps with the areas of high demand, again predominantly featuring the industrial estates and Dublin Airport.

Furthermore, the commercial heat density is mapped in Figure 26. As discussed previously, heat density is used to measure suitability for DH schemes. The commercial sector is particularly suitable for DH as it will typically have longer hours of demand than the residential sector, meaning a higher load factor for the centralised heating plant. Buildings with a steady 24 hour load, particularly public sector buildings like hospitals, are best economically and are sometimes referred to as anchor loads. The density of the demand is important as the shorter the pipe runs, the less losses and costs are involved. With this in mind, it can be seen that the areas with the highest heat demands are not always the areas with the highest heat density. In contrast to Figure 23, whereby the large industrial estates accrued the highest energy demand, Figure 26 shows these areas do not always have the highest heat demand densities. This occurs due to the industrial facilities being spread relatively far apart compared with urban commercial activities which cluster intensely around central hubs. This said, the large size and heat demand density of the industrial parks suggest a much more feasible district heating investment.

All five large industrial areas satisfy the Danish rule of thumb for DH feasibility, (150 TJ/ km^2), yet some appear more attractive prospects than others, especially to pioneer this technology in Ireland. Baldoyle Industrial Estate in particular has the highest heat demand density, as shown in Figure 27, and is surrounded by the built up residential areas of Clongriffin, Donaghmede and Bayside. This is advantageous as it provides the possibility to expand to other future customers. DH possibilities will be discussed in more detail when commercial sector energy use is combined with other sectors and total heat density is mapped.

The annual costs of energy for businesses in each small area can be seen in Figure 28. In total, the commercial sector in Fingal spends approximately €143 million annually on energy costs. Aside from the taxes, utility and network charges make up the majority of the rest of this revenue which is exported to pay for fossil fuel imports. It is not known how many of these businesses are auto-producers, but in terms of renewable energy,

Location	Total Area km2	Heat Demand GWh	Heat Density TJ/km2
Baldoyle	0.34	32.16	338.04
Damastown	1.20	72.70	218.27
Ballycoolin	2.65	134.96	183.35
Airways	1.03	44.95	156.98
Airport	1.06	50.50	171.24

Figure 27 : Map and Table illustrating the heat demand and density of large industrial parks in Fingal

the only market assessment of renewable energy in Dublin carried out by Codema (Codema, 2013) shows there is approximately 32MW installed commercial RE installations in the county of Dublin. This commercial renewable capacity amounts to approximately 106 GWh of production annually, and only a share of this is produced within the Fingal area. This is a very small share of the total 1,360 GWh consumed annually, but there are positives in that these successful installations can be highlighted and replicated as best practice examples. One such installation is the 850kW wind turbine located at County Crest in Lusk. It is the only large wind turbine in county Dublin and reportedly supplies 60% of the horticulture company's electricity demand.

If more energy was produced locally through the use of local resources by local companies, more of the money spent on energy could be kept within the Fingal area and boost the local economy. There are many opportunities now for businesses to produce their own electrical energy at a much lower cost and use sustainable fuel sources for heating requirements.

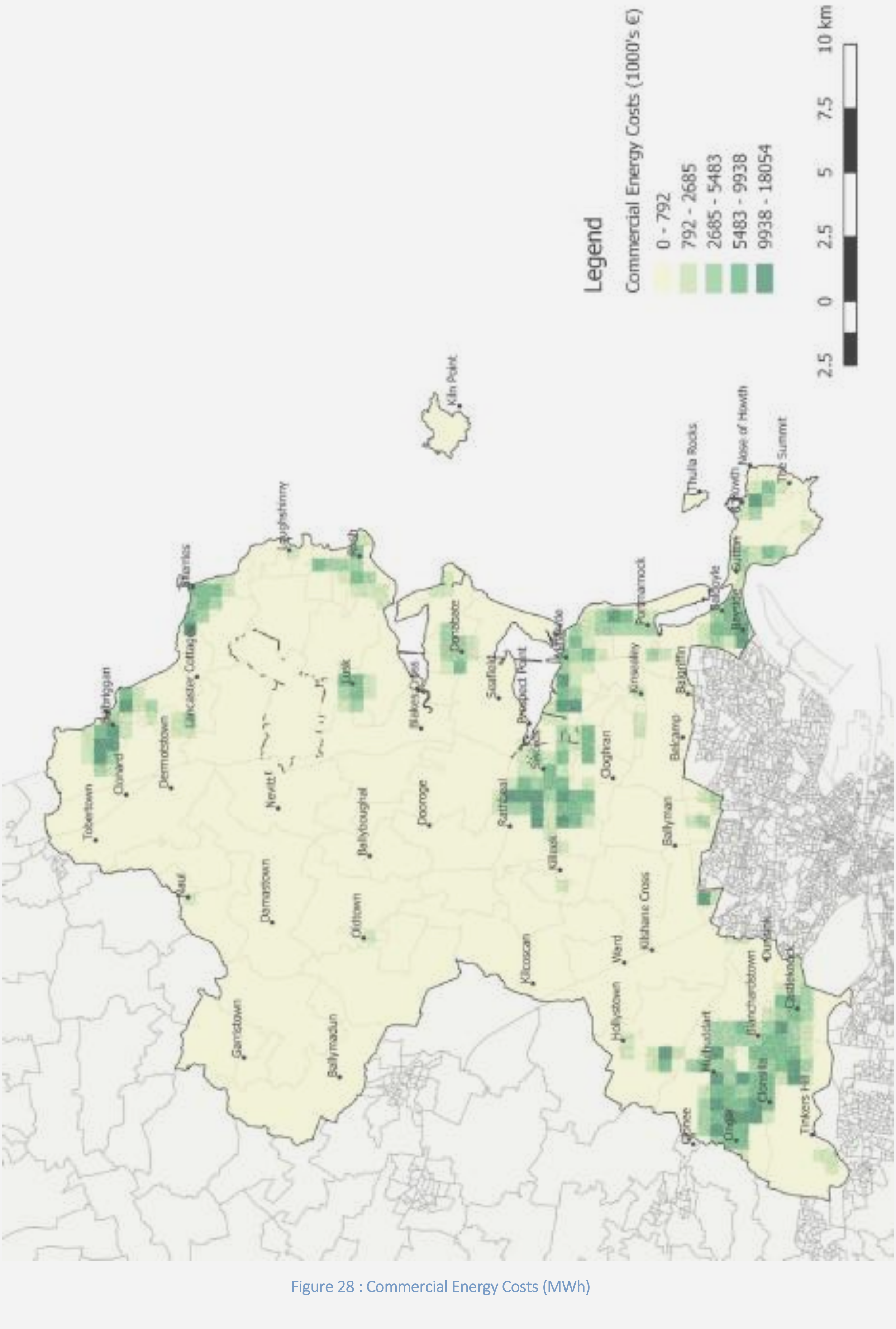

Figure 28 : Commercial Energy Costs (MWh)

Municipal Sector Energy

Fingal County Council is responsible for the energy use in a number of buildings within the county which provide services to the local authority area. There are over 500 known building-based energy accounts where FCC is responsible for the energy used. Municipal energy consumption data was available through the public sector Monitoring and Reporting tool, which lists each available electricity and gas account. After removing those accounts listed as having a zero energy demand in 2015, there are 250 FCC energy accounts mapped, with some of these sites located outside of the Fingal boundaries. The building addresses[14] were geocoded to attach to the energy data gathered for each small area. The energy use is metered energy and as such is actual rather than estimated energy use.

Figure 30 shows all of the FCC energy account locations and energy use mapped. These buildings tend to cluster around the urban hubs in Fingal, such as Swords and Blanchardstown. The Fingal County Hall and Finance Department buildings, illustrated in Figure 29, accrue to a 2.07 GWh annual energy demand. This is by far the biggest municipal energy consumer in Fingal.

The building is relatively new, having been built in 2002, but FCC has already expressed plans to perform some degree of energy retrofit and possibly include CHP production on site.

The other large energy users shown in orange and red in Figure 30 are mainly made up of similar large office buildings, fire stations and leisure centres, with some other buildings such as art museums and elderly homes also having high energy demands. These buildings also have very high energy costs, particularly those with high electricity demands due to the high cost of electricity. Other sites which may not have very high energy use, but the energy use of the site is all electrical energy, also rank highly in terms of energy costs, such as electricity provisions for halting sites.

The areas within Fingal with the highest municipal energy demand can be seen in Figure 31. Those highlighted in orange and red are areas with either one large energy user, or an accumulation of different buildings which are located very close to one another, such as areas like Swords, where a mix of public leisure centres, libraries, community halls and the County Hall are within close proximity.

Figure 29 : Municipal energy users including Fingal County Hall

FCC Building	Heat Demand (GWh)	Electricity Demand (GWh)	Total Energy Demand (GWh)
County Hall, Swords	0.89	1.18	2.07
Portmarnock Sports & Leisure Centre	0.53	1.19	1.72
Blanchardstown offices, Dublin 15	0.39	1.08	1.08
Donabate Portrane Community Centre	0.18	0.35	0.53
Phibblestown Community Centre	0.00	0.47	0.47

Table 4: Top Five Energy Consuming Buildings in Fingal

Additionally, the top five energy consuming FCC buildings are presented in Table 4.

Implementing good practice in energy management in public buildings and leading the way in sustainable energy practices in the public sector is a good way to showcase sustainable solutions as the public will often visit these premises, and also to encourage commercial buildings by leading by example.

[14] Approximately 50 of these account addresses could not be geo-coded and therefore could not be mapped. Although every effort has been made to obtain accuracy those which have been geo-coded may not be at the exact location of the building but within the same general area.

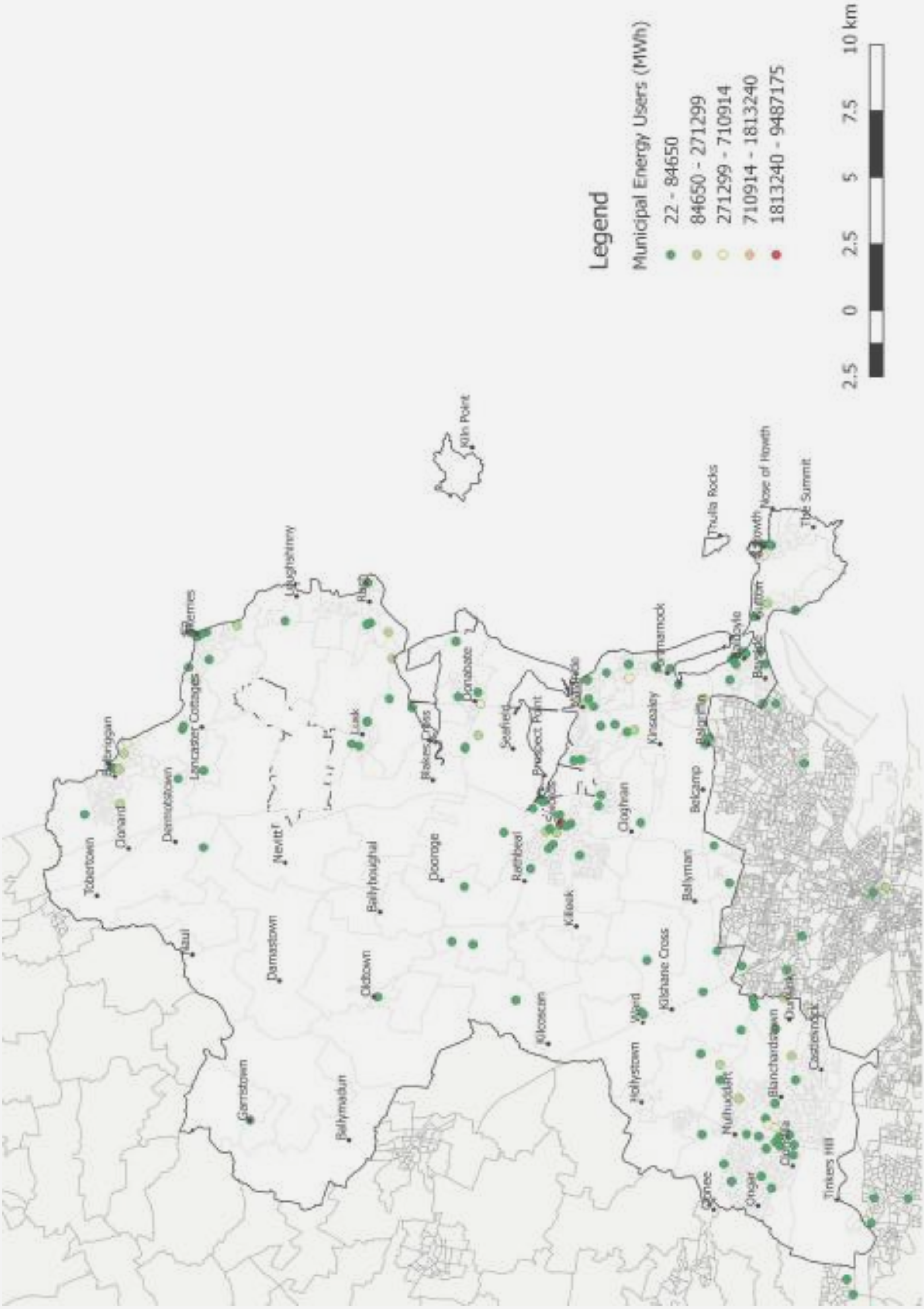

Figure 30: Municipal Energy Use (MWh) and Locations of Each Account

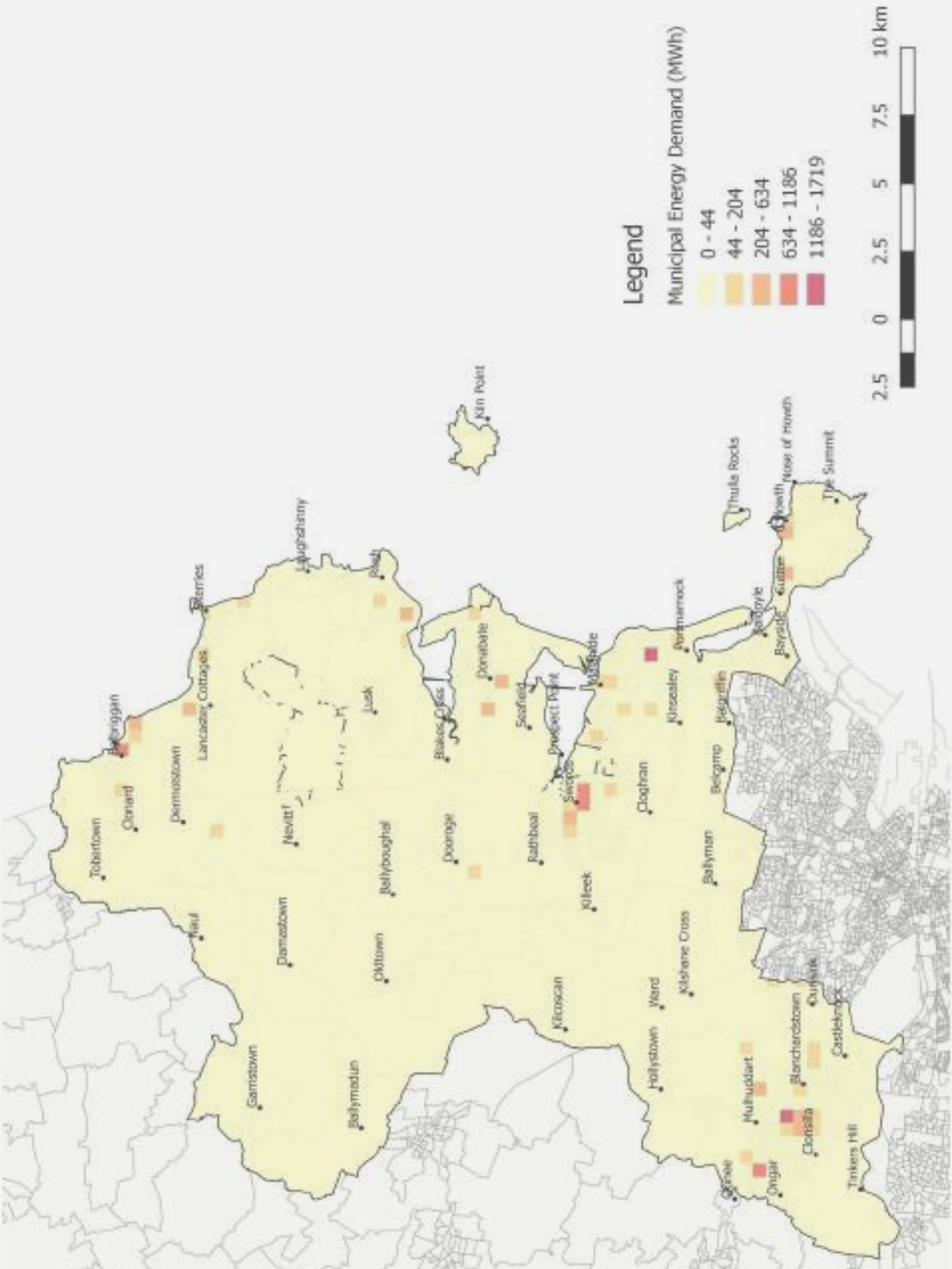

Figure 31: Total Annual Municipal Energy Demand (MWh)

Agricultural Sector Energy

Methodology

A spatial energy demand analysis has never before been performed for the agriculture sector in Ireland. Fingal is known to possess a considerable agricultural and horticultural industry, and so it is important to include these demands in any spatial analysis of energy use. For this reason, an original methodology has been developed in order to gauge the level of agricultural activity and approximate energy use based on the best available spatially related data.

The agricultural sector in Ireland has very little publicly available data combining activity types, intensity and spatial information. In order to gather and incorporate these pieces of information, several sources were utilised including the CSO, OSI and a number of reports concerning direct energy use in agriculture. The CSO, through the Census of Agriculture mapping software, presents figures on animal farming (number of cows, sheep, horses, etc.) and crop farming (hectares of cereals, potatoes, hay, etc.) activities within each Electoral District (ED) in Ireland. Due to privacy protection concerns, any ED containing less than ten farms is not included in the data breakdown.

Farming activity breakdowns per ED are given for the entire Dublin region. After excluding the EDs with less than 10 farms, 98% of total farms remain. However, this may include some double counting for farms which border two EDs and again may vary slightly for Fingal specifically. The CSO also gives figures regarding field vegetables for the whole of Dublin, and it could be assumed the majority of this activity would be in Fingal, however, no further location-specific information is available, and so these have been left out of the mapping analysis.

A more precise spatial account of crop-based agricultural activity may have been available through access to the Land Parcel Information System (LPIS) data, which documents the location and crop type of each farm in Ireland receiving EU payments. Unfortunately, it was not possible to access this database within the time constraints of this project. Field crops do however consume a comparatively low amount of direct energy per hectare when compared with horticultural activities and so this does not drastically impact the mapping results.

The activity figures from the CSO census of agricultural data are then combined with standard agricultural energy use benchmarks, as developed by Teagasc, the UK Carbon Trust and the Department of the Environment, Food and Rural Affairs (DEFRA) in Britain. It is the intention to use benchmarks that relate as close as possible to Irish agriculture.

The CSO does not give information at any smaller scale than regional (Dublin) for horticultural activities, especially protected crops which are grown in glasshouses or polytunnels. For this reason, a separate method is employed to gauge the level of this activity. For the purpose of this report, Fingal County Council issued a digital map of all buildings in Fingal, including glasshouses. This information was then cross referenced with 2016 Google imagery to check for inconsistencies. Glasshouses less than 150m^2 were excluded in order to eliminate residential greenhouses.

Unfortunately, it is not possible to discern exactly what type of protected crop is being grown. For energy benchmark purposes, Teagasc and the UK Carbon Trust separate these crops into extensive (e.g. lettuce) and intensive (e.g. tomatoes, cucumbers, etc.). For the purpose of this report, an average was taken of these two energy use benchmarks and applied to all glasshouses.

To spatially represent the agricultural energy data, the EDs featured in the CSO agricultural data are converted to grid format for the sake of consistency with the mapping throughout this report.

Results

The breakdown per agricultural activity in Fingal is illustrated in Table 5, whereby animals are expressed in livestock units (LU) and crops are expressed in hectares (ha). Of the four Dublin LAs, Fingal has by far the largest agricultural industry, accounting for around 68% of all land farmed in Dublin County. Of this land area, the majority is occupied by cereal crop growth. The direct energy consumption in tillage farming is quite low per hectare, with the primary fuel being agricultural diesel used in machinery. There are far fewer hectares of potatoes than cereal crops grown in Fingal, yet this crop is much more energy intensive and so the total energy is comparatively higher per ha, as seen in Table 5.

In terms of livestock, the greatest quantity is seen to be sheep, with over 18,000 present in Fingal. Again, sheep farming is a relatively low energy activity, accounting for only 0.06% of total energy demand from the agricultural industry. Dairy cows are the most energy intensive livestock from the animals used in these calculations, with a total energy demand of 875 kWh per annum per cow.

This takes into account electricity used in milk extraction and cooling, as well as fuel used in field work. Numbers of pigs and chickens are available for the entire County Dublin but unfortunately nothing specific to Fingal. Thus, these livestock have been excluded from calculations. The impact of this exclusion is, however, insignificant as the summation of all related energy in Dublin is a maximum of 61 MWh per annum.

It is unsurprisingly the protected crop industry which is the most energy intensive aspect of this sector. This, coupled with a considerable presence in Fingal, means that 87% of all agricultural energy demand comes from glasshouses and polytunnels. As depicted in Figure 33, the primary energy demand within the agricultural sector is situated between Killeek and Swords, in the glasshouses of Keelings, Donnelly's Fruit & Veg and Roslin Food Park. This area alone accounts for 64% of total agricultural energy demand in Fingal. A zoomed in depiction of this is seen in Figure 32 whereby these expansive glasshouses can be seen adjacent to residential buildings near Swords.

Activity	Quantity LU or ha	Energy GWh
Dairy Cows	1705	1.49
Other Cattle	11881	5.38
Total Sheep	18019	0.34
Horses	387	0.18
Total Cereals	8611	13.09
Potatoes	1763	8.70
Silage	2078	2.69
Hay	1148	1.49
Total Energy		33.36

Table 5 : Breakdown of Agricultural Activity in Fingal

Figure 32 : High Energy Using Horticultural Glasshouses in Fingal

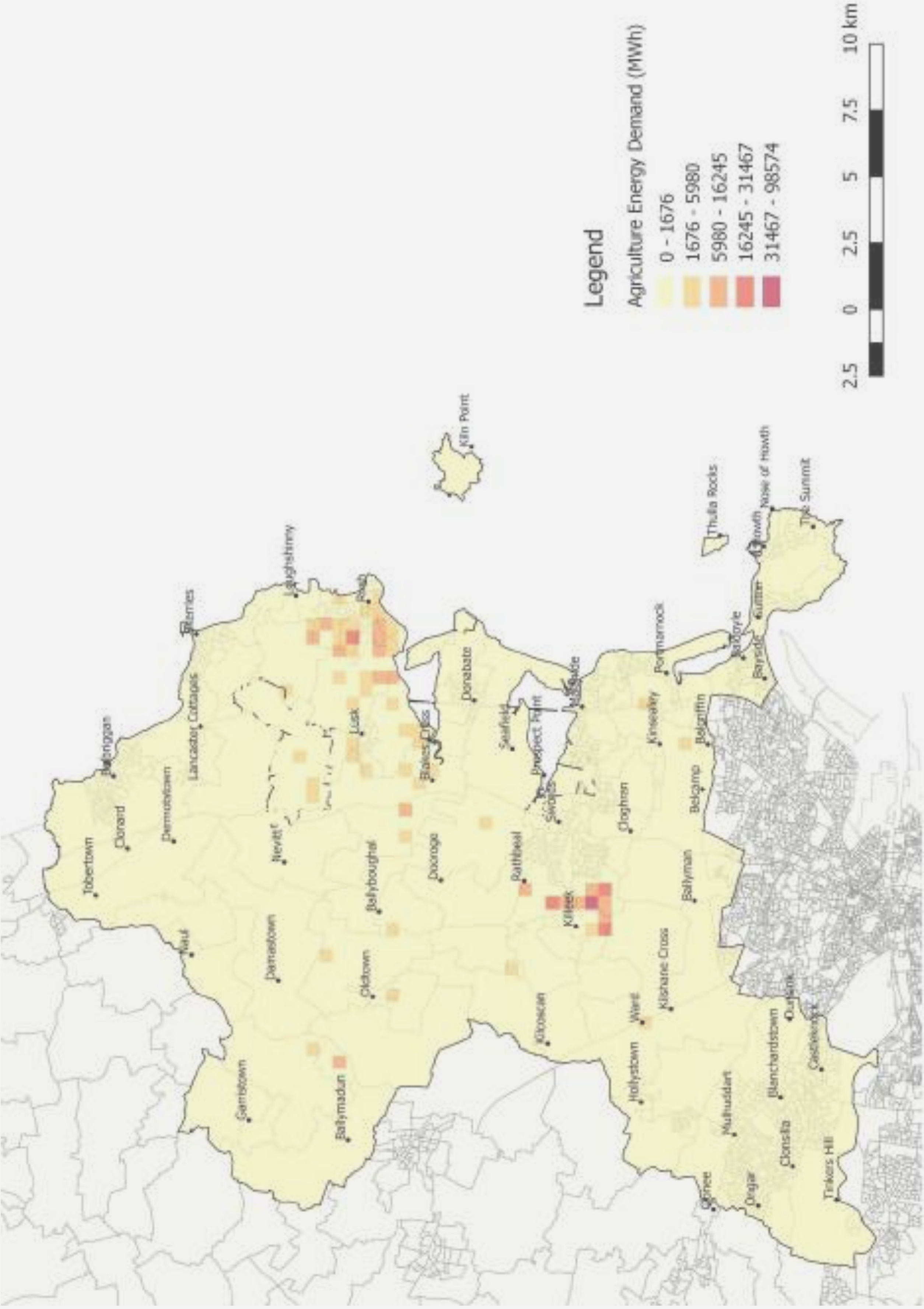

Figure 33 : Total Agricultural Energy Demand (MWh)

Another area of high agricultural energy use is situated in the surrounding areas of Rush in north Fingal. This area does not feature glasshouses of the scale and concentration seen near Killeek, but instead has smaller and more dispersed producers.

The direct electricity usage of the agricultural sector in Fingal is presented in Figure 34. The distribution of demand is consistent with that of Figure 33, although the quantities of electrical energy listed in the legend are considerable smaller. This is due to the fact that in the agricultural activities present in Fingal, electricity is not a large factor in the energy use. There is a negligible amount used directly in tillage farming, as well as sheep and non-dairy cow farming. The electricity use in protected crops is also very small, accounting for only 3% of total direct energy usage for these crops. Commercial glasshouses do, however, require particularly high heat energy usage to maintain the high temperatures within, especially during winter. Of the total energy demand, heat accounts for 97%. The spatial concentration of these glasshouses, especially in certain parts of Fingal, means that there are some areas with exceptionally high heat density. As illustrated in Figure 35, these are situated at the hubs of horticultural activity in Fingal, near Killeek and Swords, as well as in Rush.

The glasshouses of Roslin Food Park and other producers are situated relatively close to the commercial and residential hub of Swords. Future growth in all of these sectors could see the closing of this spatial gap, creating a large area of high energy, and in particular, heat demand in Fingal. The very high heat demand of these glasshouses acts as the perfect anchor load for a district heating network, while the adjacency of commercial and residential areas means that future expansion could be possible, even highly profitable. This will be discussed further when addressing heat density for all sectors combined.

Figure 36 shows the financial costs of this energy demand for the agricultural sector in Fingal. Again, the spatial distribution follows a similar pattern to the various energy demands. However, an interesting aspect of this result is that the costs are not as high as may be expected given the level of energy demand. This occurs because the primary fuel used is overwhelmingly natural gas, with smaller amounts of diesel and electricity. Electricity is much more expensive per MWh and so the costs are lower. Additionally, the high level of use per farm means that many enter into the high user cost bracket and therefore receive better prices per MWh.

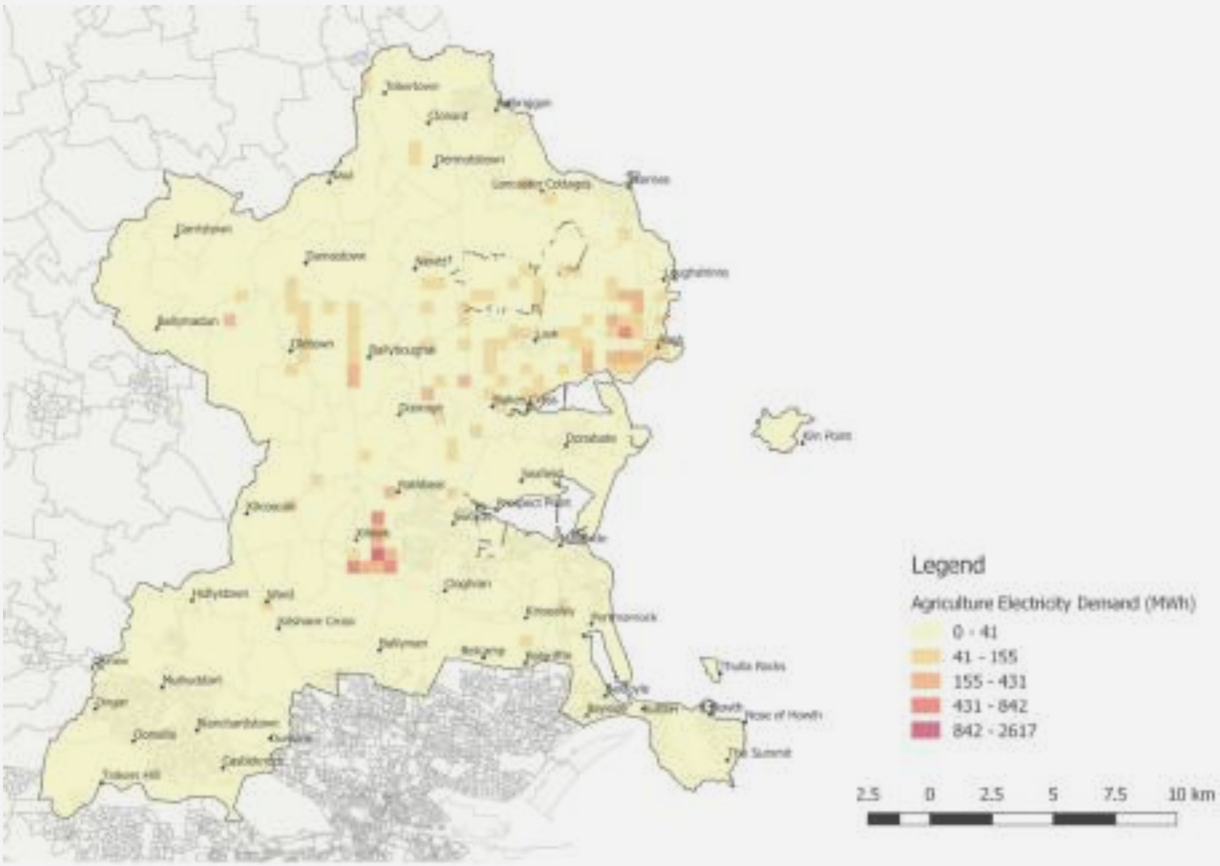

Figure 34 : Agricultural Sector Electricity Demand (MWh)

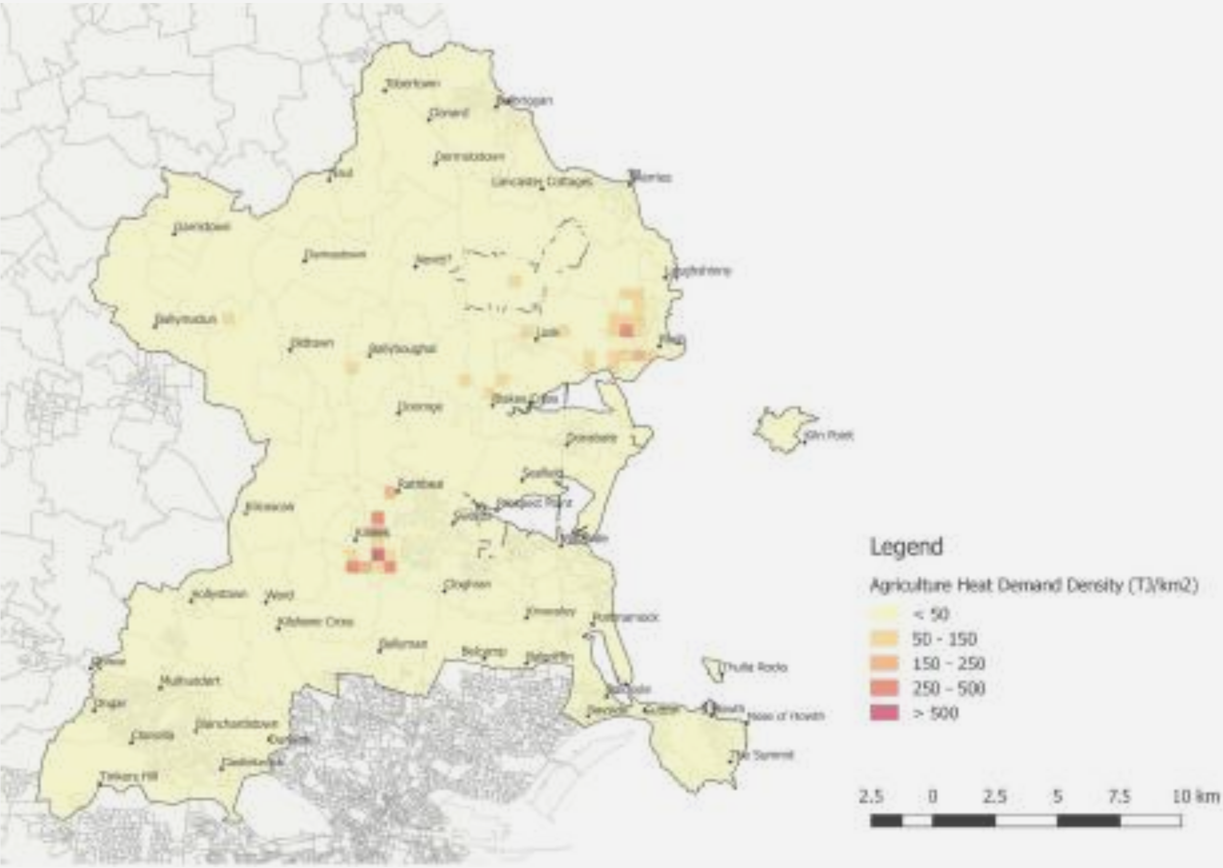

Figure 35 : Agricultural Heat Demand Density (TJ/km2)

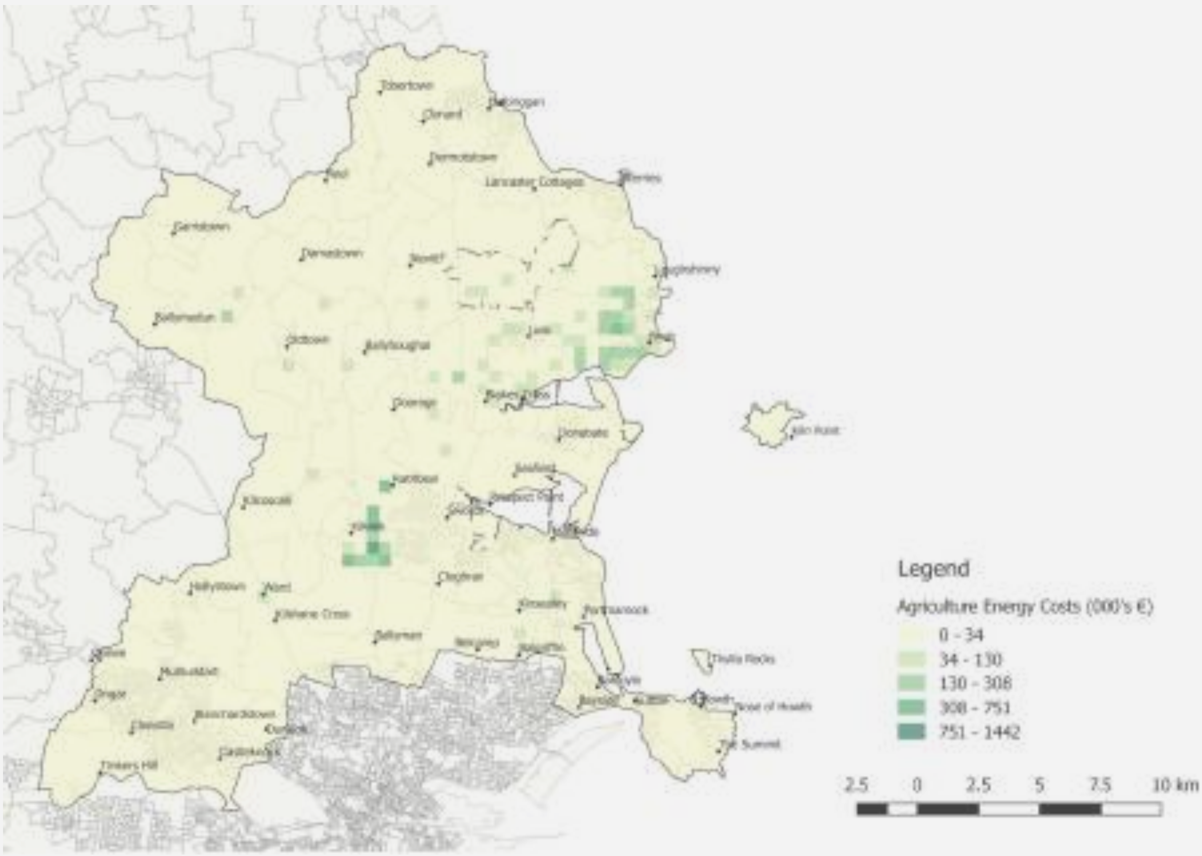

Figure 36 : Agricultural Energy Costs (Euro)

Total Energy in all Sectors

This section examines the resulting total energy demand throughout Fingal once all residential, commercial, municipal and agricultural energy demands are combined.

Total Energy Demand of All Sectors Combined

The total direct energy use in all sectors analysed in this SEDA is 4.02 TWh annually, as illustrated in Table 6. Of this, 3 TWh is used to meet heating demands which is equal to 75% of overall energy use. This is a large amount of energy being used to heat buildings and for industrial heating processes.

Due to the current energy mix in Ireland, especially for the heating sector, this means that fossil fuels provide the vast majority of energy consumed in Fingal. The difference between fossil fuel use and heat demand takes into account fossil fuel consuming machinery in industrial and agricultural practices.

A map showing the total annual energy demand throughout the county can be seen in Figure 37. The highest areas of energy use are dominated by those with large industrial and horticultural activities, as well as clusters of commercial activity. The range of demands coloured light orange represent mainly residential and lower scale commercial areas. The light and dark red areas tend to be those containing large commercial glasshouses, industrial estates or urban hubs such as Swords. These large industries tend to spatially disperse the energy demand in Fingal so that it does not convene around one central fulcrum, but rather in a number of different areas, depending on the sector in question. Population density is not seen to be indicative of high energy use as there are many less densely populated areas which have high energy demands due to the presence of food processing, protected crops and pharmaceutical factories. Since these areas are further away from built up areas, they can have advantages for renewable energy integration, such as less traffic issues regarding transport of biofuels and biomass, distance from dwellings which may make it easier to implement small to medium scale wind power, and in terms of PV installations, potentially less over-shading issues from neighbouring high-rise buildings.

In order to match RE technology to energy demand, it is important to understand how much demand for heat, fossil fuels and electricity is needed in each area. Implementing a large CHP unit in an area to meet electricity requirements is no use if there is not sufficient local heat demand. Buildings with large heat demands, small electricity use and south facing roof spaces may be better suited to solar thermal installations than solar PV.

Table 6 shows the total annual fossil fuel consumption throughout Fingal. It can be seen that the distribution of fossil fuel use follows closely the distribution of total energy use as fossil fuels are so dominant in every sector’s energy mix.

The high use of fossil fuels in the residential sector, which is mostly used for heating needs, can be replaced with renewable and sustainable solutions. When looking to replace a gas or oil boiler, households should be encouraged to prioritise the most sustainable options. As mentioned earlier, there are grant supports for homeowners installing new gas or oil boilers, but no supports for biomass or biofuel boilers, or any heat pump systems. This limits homeowners’ options; the only RE heating solution supported is solar thermal, but not all dwellings will be suited to this solution. Commercial sector buildings which are planning to install CHP units sized to offset electricity use could look at providing nearby households with heat, thereby allowing the CHP to run at high efficiency mode for longer, produce the maximum amount of electricity possible, and create an additional revenue stream. As can be seen in the maps, there are plenty of heating demands in close proximity to large commercial buildings.

Sector	Total Energy (TWh)	Total Heat (TWh)	Total Fossil Fuel (TWh)	Total Electricity (TWh)	Total Costs (€millions)
Residential	1.99	1.70	1.58	0.41	170.78
Commercial	1.38	0.76	0.91	0.48	143.27
Municipal	0.03	0.01	0.01	0.02	2.46
Agricultural	0.62	0.53	0.59	0.03	15.29
Total	4.02	3.00	3.09	0.93	331.80

Table 6: Energy Demand Breakdown per Sector and Fuel in Fingal

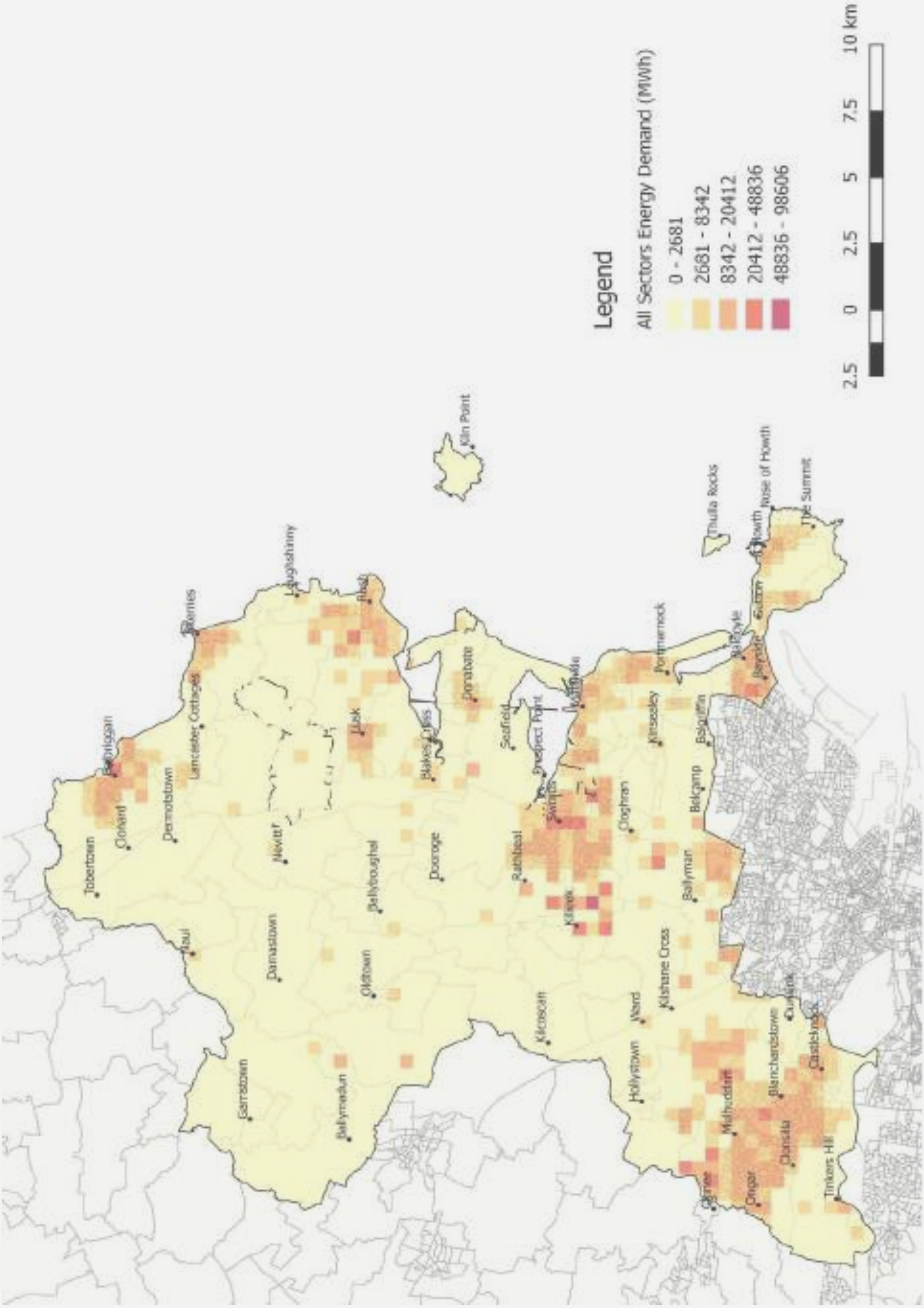

Figure 37 : Total Annual Energy Demand of All Sectors (MWh)

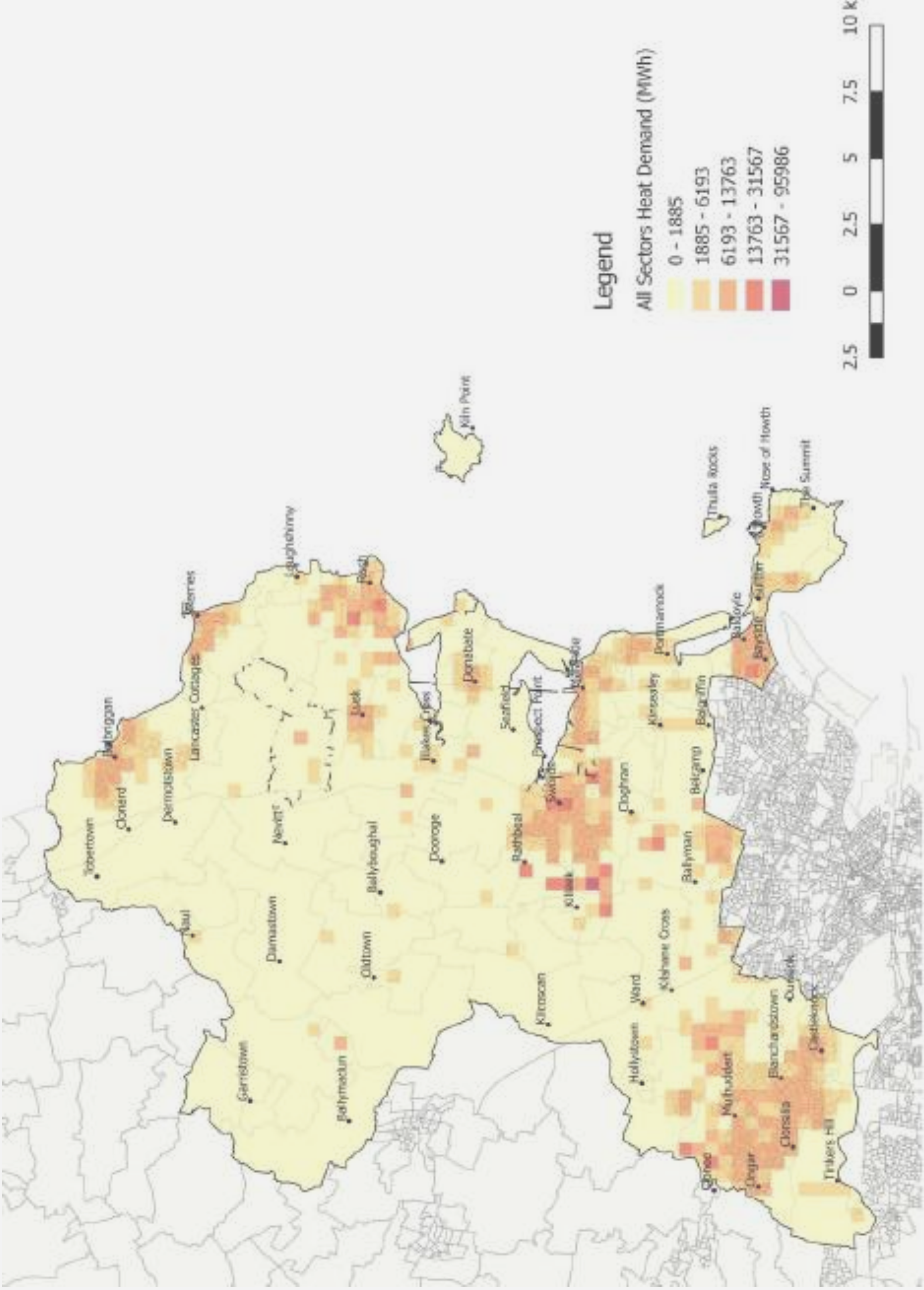

Figure 38 : All Sectors Heat Demand (MWh)

The total electricity demand in Fingal is presented in Figure 41. In contrast to the demand of fossil fuels, the distribution of electricity demand does not follow that of total energy demand so closely. The highest levels of electricity usage tend to be in areas dominated by commercial and industrial activities, not residential or agricultural. The latter is, as previously discussed in the Agricultural Sector section, due to commercial glasshouses having a very low electricity demand in comparison with their heat demand. Additionally, most residential areas will typically have 25% or lower electricity share of total demand.

In contrast, the industrial estate such as Ballycoolin and Baldoyle will have high electricity consumption due to the presence of electricity intensive activities such as pharmaceutical factories and food processing. These areas will most benefit from a source of low cost renewable electricity to offset the high costs of grid electricity. In terms of alternatives, wind, hydro and solar PV are all well-established renewable electricity generating technologies, with bio-fuelled CHP a highly efficient sustainable option for businesses which also have a heat demand.

The total cost of energy use annually in Fingal is €331.8 million; €170 million in the commercial sector, €143 million in the residential sector, €2 million in the municipal sector and €15 million in the agricultural sector. The areas with the highest energy spends are highlighted in dark green in Figure 42. The highest energy spends again follow the electricity demand rather than the total energy demand distribution. This overlaps consistently with areas of high commercial energy consumption, and particularly the industrial estates. The costs in the areas shown in dark green range from €5.8 to €10.8 million annually.

District Heating Potential

As discussed in the introduction, heating is fundamentally a local and regional issue and national level energy strategies often do not deal with heating effectively. As there is no national heating grid, in the same way as there is a national electrical grid, there is no real way to deal with heating from a top down approach. Typically, heat is provided by individual heating plant and equipment within each building, fuelled mainly by gas in the case of Fingal.

DH is a real way to influence the way we currently think about heating provision. This more holistic approach to meeting heating requirements means one large highly efficient renewable or sustainably fuelled heat plant can supply almost all of the heating requirements to numerous buildings without the need to pressure each individual to install a new renewable heating system in their building.

The heat density of each grid division is shown in Figure 43. Using the same thresholds for DH viability typically used by Danish energy planners in their own municipality areas, there are a number of areas in Fingal that would be classified as suitable for DH.

As discussed in previous sections, the areas with the most highly concentrated heat demand are those with considerable industrial and horticultural activities present. However, it is highly preferable for these anchor loads to be adjacent to residential communities in order to maximise possible demand and improve viability. There are also many areas dominated by residential buildings which have mid-range 150-250 TJ/km^2 heat densities which would also be deemed very suitable for DH schemes. This is particularly the case with the Baldoyle Industrial Estate, which is situated in between the residential hubs of Bayside and Donaghmede. These areas have an ageing housing stock and dwellings with old heating systems which have low efficiencies. Many of such housing units will soon look to replace these systems, and implementing a DH system instead of multiple individual fossil fuel boilers will create lower heating costs due to economies of scale and will allow easier integration of RE and waste heat sources into the heating systems of these homes.

Another area of high potential, depicted in Figure 39, is that of the horticultural hub in between Killeek and Swords, including Keelings and Roslin Food Park. The distance to Swords is just over 3km, so it is highly possible that a district heating system could connect these high consuming horticultural anchor loads to a growing residential and commercial population. An interesting precedent is presented in Figure 39, whereby the Copenhagen DH system, the largest DH system in Denmark, was established in Copenhagen City Centre, and the network has expanded all the way to Roskilde, which is approximately 40km away.

Figure 39 : The Greater Copenhagen DH System (Danish Energy Agency)

The network can expand to these areas by connecting new heat generation facilities along the route, such as large CHP plants, waste heat from cement factories, incineration plants, etc.

Anchor loads for DH systems are loads which allow the heating plant to run for longer hours (e.g. 24-hour demands), have a more steady load than other demand types (less large peaks in demand) and are likely to be based in the same building for a long time. These are identified by green squares in Figure 44. It is often preferable that these customers are in the public sector as they are likely to be a more financially secure customer. These may include hospitals, nursing homes, large industrial facilities with heat demands, leisure centres, colleges, and fire stations. The municipality-owned potential anchor loads are presented using gold stars in Figure 44.

Waste heat sources, seen as red circles in Figure 44, can generally be provided at a much lower cost than other heat sources, and can therefore have a very positive effect on DH system economics. These industries include large bakeries, breweries, concrete works, large factories and energy generation plants. The exact amount and usefulness of this waste heat should be further analysed, along with CHP plants.

If the high energy users within the horticultural and industrial estates were to switch to a sustainably fuelled district heating network, it would have a huge effect on the current fossil fuel demands and CO_2 emissions in Fingal, and the overall sustainable image of the county. This SEDA gives the local authority the information they need to begin the process of effectively planning for DH networks throughout the DCC area.

Figure 40 : Areas of High Potential for District Heating Scheme near Swords

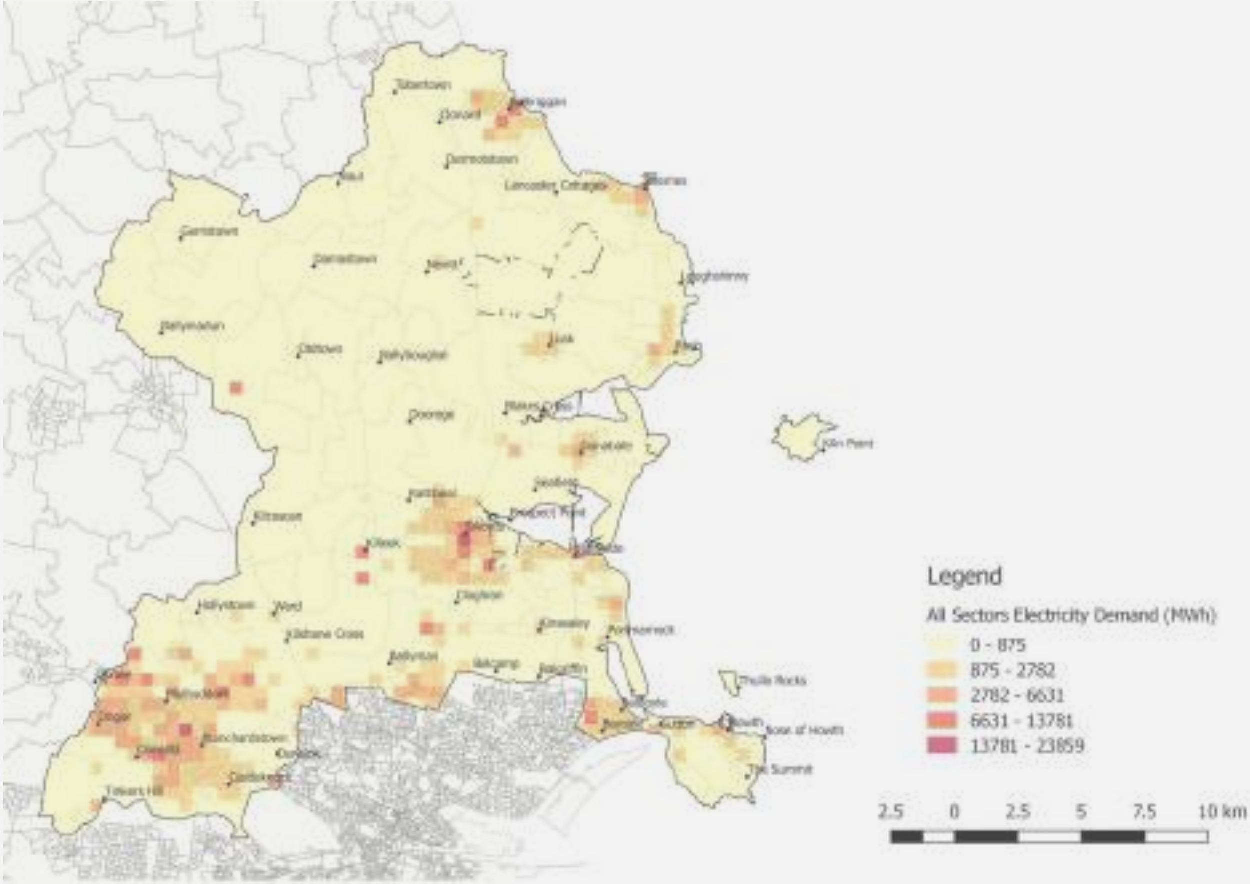

Figure 41 : All Sectors Electricity Demand (MWh)

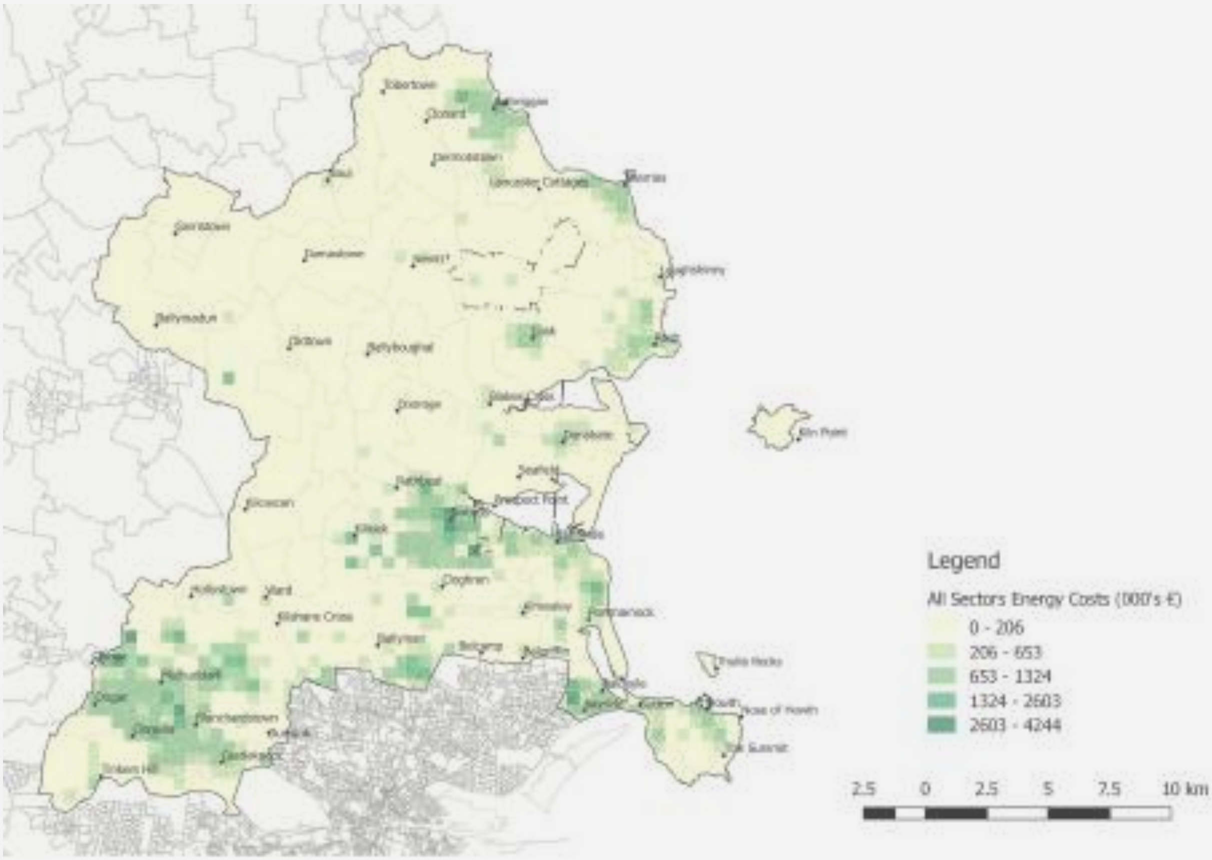

Figure 42 : All Sectors Energy Costs (€)

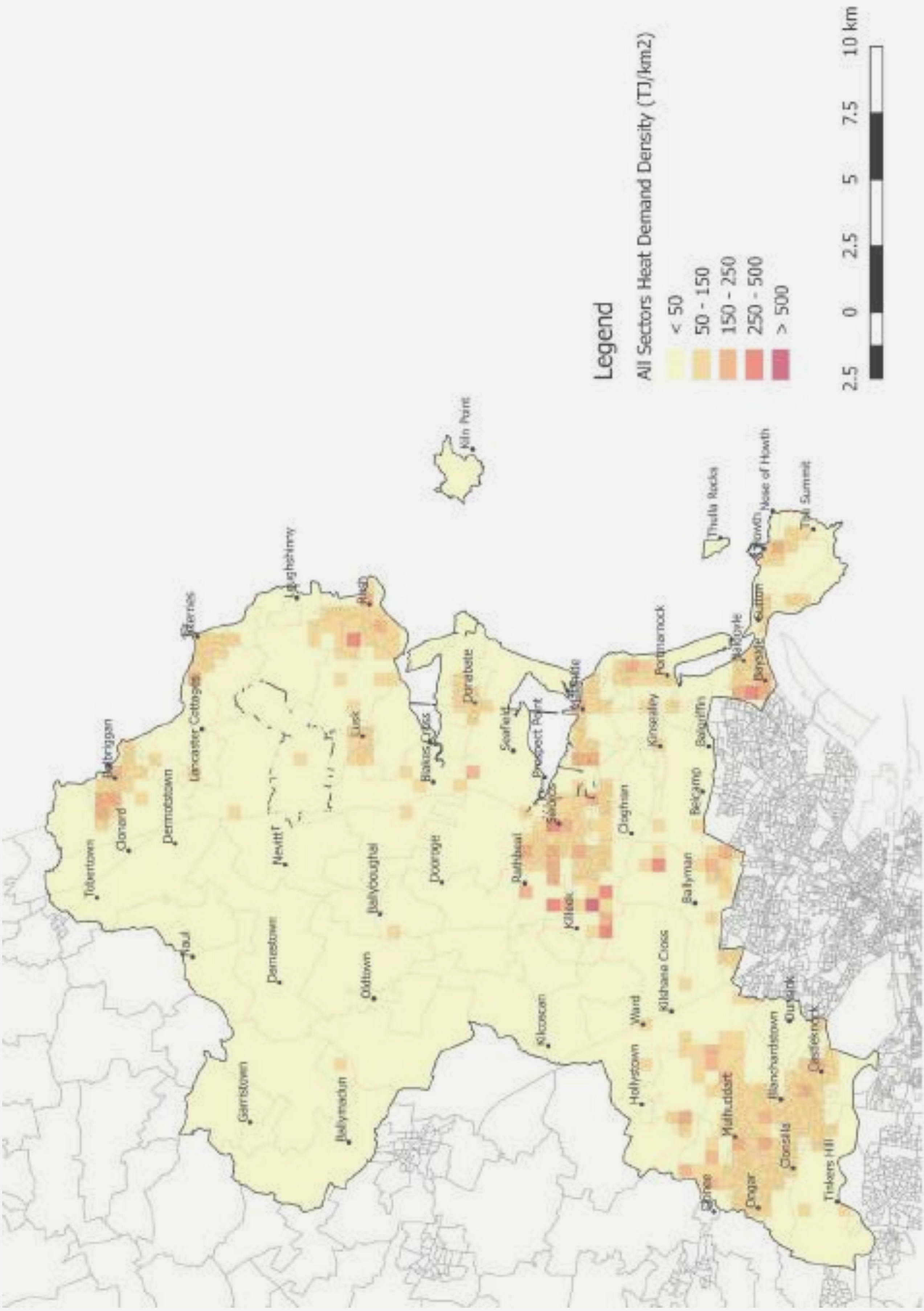

Figure 43: All Sectors Heat Demand Density (TJ/km^2)

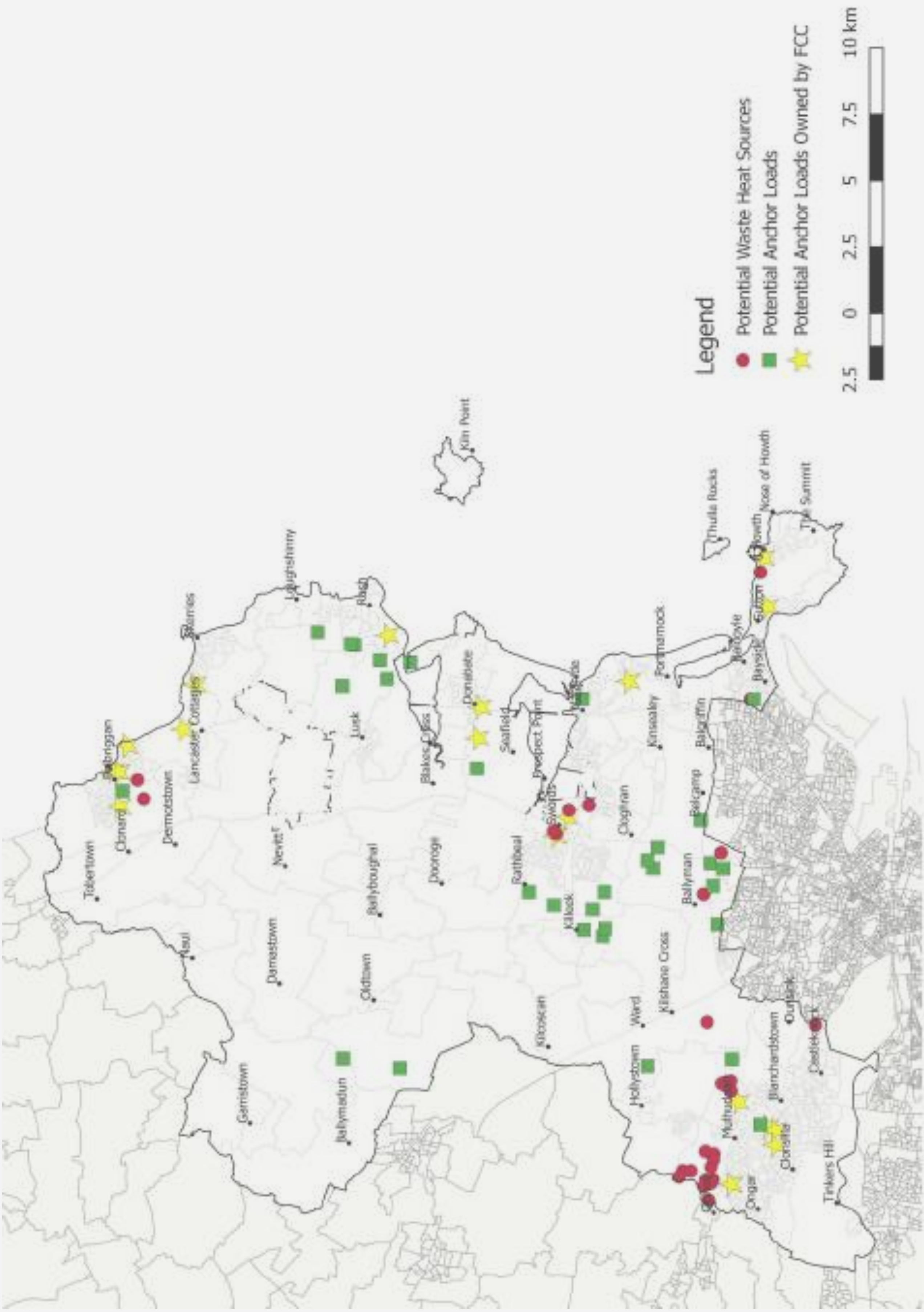

Figure 44 : Potential Anchor Loads and Waste Heat Sources

Renewable Energy Resources in Fingal

This SEDA has shown a spatial representation of the energy demand in Fingal. The type of energy demand and location of this demand is specific to Fingal, due to many influencing factors such as the building construction periods, availability of fuels in this area, topology, geography and urban and spatial planning regulations. This region will also have renewable resource potential specific to this landscape, influenced again by many local factors such as the geology, anemology, hydrology, geography and urban and spatial planning regulations of the area.

Important to note in terms of financial feasibility of all small-scale renewable installations is that there are currently no feed-in tariffs being offered for power fed to the grid from micro-generation installations. This means that the size of these installations needs to be carefully matched to the owners' own power demands so that all power produced is used and not exported without payment. Commercial scale installations can negotiate a power purchase agreement with utilities and can apply for Renewable Energy Feed-In Tariffs (REFIT), which are available depending on eligibility.

Geothermal Resources

Geothermal energy is solar energy stored in the form of heat within the earth's surface, heating the soil itself or groundwater beneath the surface. It is used to produce heat to meet building heating requirements, and can produce both space and hot water heating, but is most commonly used for low-temperature space heating.

The makeup of the soil and bedrock in Fingal will affect the suitability and potential to exploit geothermal resources. Geothermal resources are classified into 'shallow' and 'deep' geothermal resources. Shallow geothermal is a relatively low temperature heat source found up to 400m below the surface and is boosted through the use of a heat pump to useful heating temperatures. Deep geothermal involves drilling boreholes deeper than 400m below the surface to obtain higher ground-source temperatures usually hot enough to use directly. A good example of geothermal energy in Ireland is IKEA's 1.5 MW installation at their store in Dublin 11. The project consists of 7 ground source heat pumps, 150 boreholes, and is the largest of its kind in Ireland or the UK.

Figure 45 : Maps showing the vertical closed loop geothermal (left) and open loop domestic geothermal (right) suitability within Fingal County (SEAI, 2004).

The Geological Survey of Ireland (GSI) Shallow Geothermal Energy Resource Project has produced maps which show the shallow geothermal energy suitability of areas across Ireland. The maps show the suitability of different types of systems (open loop and closed loop) and for both domestic and commercial applications. These maps can be accessed on their website at http://www.gsi.ie/Mapping.htm. As can be seen in Figure 45, Fingal has a significant area classified as very suitable for both open loop and closed loop geothermal energy. In relation to the former, the south and north west areas are where the majority of this resource is currently known to be available. For the latter, a thick strip in the north of the county, from Loughshinny to Garristown, is considered to be the most eligible location. Aside from this, there are many areas classified as suitable, probably suitable and possibly suitable for geothermal technology. This suggests a considerable resource could be available to the inhabitants of Fingal.

The GSI has also produced a homeowner manual for ground source and geothermal energy which explains the whole process and terminology involved, and estimated costs of installations, which can be found on http://www.gsi.ie/Programmes/Groundwater/Geothermal.htm

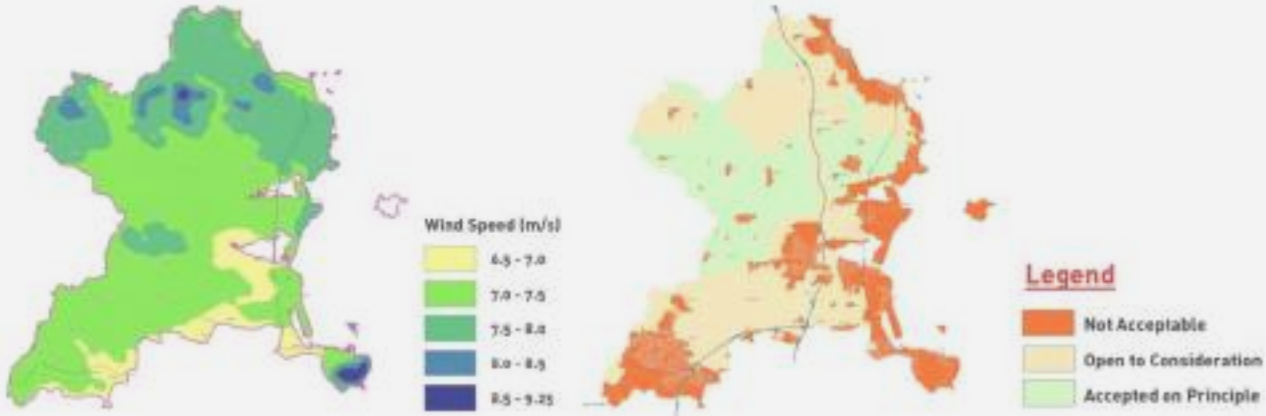

Figure 46 : Maps showing the average wind speed (left) and spatial suitability (right) of wind farms in Fingal.

Wind Resources

Wind turbines are a well-established technology for producing electricity and Ireland's vast wind resources have been exploited using this technology and contribute greatly to the renewable electricity mix nationally. In Fingal, there is a wide variety of land use. In the urban and residential hubs such as Swords, Blanchardstown and Donabate, wind power technology may not be suitable due to the lack of space, low altitude and disruption of laminar flow caused by buildings and other obstructions. However, there is a significant amount of lower populated, rural land in Fingal which could facilitate wind turbine installations, given the support of the local communities. As previously mentioned, the example of the Lusk based vegetable producer, County Crest, installing on-site wind power generation shows how businesses in Fingal can use local renewable resources to reduce their energy costs and carbon footprints. There are some other stand-alone turbines in the county of Dublin, many of which have been identified in Codema's RE market assessment, which can be downloaded at this link: http://www.codema.ie/images/uploads/docs/Renewable_Energy_Report.pdf

Fingal County Council, recognising that wind energy would be a vital part of Ireland's future energy mix, developed a Wind Energy Strategy (Fingal County Council, 2009). This document outlines the available wind resources, topographical conditions and sensitivity of certain areas to planning conflicts. Figure 46 illustrates both the wind resource and spatial suitability, as published in the Wind Energy Strategy. The above wind speeds were recorded and mapped by ESB International, at a height of 75m and show all of Fingal to have ample wind resources. It is considered in the same Wind Energy Strategy that anything above 4 m/s is desirable. (Fingal County Council, 2009). Areas where wind speeds are highest include Howth, the north-west coast of Fingal and the rural areas to the south of Naul and Garristown. However, these are less encouraged than others, with much of the most desirable areas being deemed unacceptable due to the proximity to residential areas, and in some cases, the visual impact on coastal areas. Nevertheless, there is a vast area in Fingal with feasible wind resources that are either accepted on principle or open to consideration.

Hydro Resources

Hydroelectric power involves the production of electricity through a generator which is powered by the force of moving water. It is used at very large scales in some countries which have vast river resources and high mountainous areas, such as Brazil, where hydropower provides over 75% of the country's electricity. The biggest hydro sites in Ireland are found at Ardnacrusha, Cathleen's Fall and Pollaphuca, the latter being fed by the River Liffey. Suitable sites are sites where there is a running flow of water year round, where this flow has a high fall height (or head height), and where re-routing the water resource through a turbine will not have a negative effect on the environment. Schemes can either use the flow of the river directly ("run-of-river" schemes) or build a small dam or reservoir to increase the flow when the river has a low flow rate. A site assessment measuring the quantity and speed of flowing water should be conducted to evaluate the potential hydro power output. A very useful guide on how to develop small scale hydro power is available from the European Small Hydropower Association at the link: http://www.esha.be/fileadmin/esha_files/documents/publications/GUIDES/GUIDE_SHP/GUIDE_SHP_EN.pdf

Fingal has two main rivers, the Tolka, and the Liffey, with many other smaller rivers feeding into the

Rogerstown Estuary. There is no water flow data available for hydro resources in Fingal. However, it is quite a flat land area, and so head heights on these waterways will not be very substantial. The higher the head height, the higher the flow speed of water and the more power can be generated. Mountainous areas, closer to the Dublin Mountains, would be more suitable. The afore mentioned Renewable Energy in Dublin Market Assessment report carried out by Codema identifies a plan for a hydro-electric plant at Hills Mills near Lucan Weir. The intention would be for this system to power an upgraded public lighting system in Lucan Village. However this is not currently operational (Codema, 2013).

Solar Resources

Solar energy production involves using the energy from the sun to produce either heat or electricity. Solar thermal installations use the heat energy from the sun to heat water, and solar photovoltaic (PV) installations convert energy from light into electricity. The only resource needed for these installations is a space which is facing the daytime sun direction (south-southeast is best in Ireland) and is free from nearby tall obstacles which may cause over-shading issues.

Figure 47 : Solar Suitability Map, Copenhagen

From analysis of actual PV installations in Fingal, the solar resources in Dublin allow approximately 800-1000kWh/kW/year to be produced with a south facing installation. A 1kW installation will therefore provide approximately one fifth of the average household's electricity requirements and save €250/year on electricity bills. If all houses (not including apartments) in Fingal installed only 1kW of PV panels on their roofs, the potential output is over 81.8 GWh/year, which is nearly 20% of the residential sector electricity demand[15]. Solar power has real potential in Fingal, and in order to further analyse the total solar electricity potential resource, a solar atlas which outlines the viability of each roof space should be created. Similar atlases have already been developed in other countries, such as that available in Denmark, an example of which can be seen in Figure 47. This map outlines each roof space and is colour coded to show if the roof is suitable or not suitable for solar PV.

The costs of solar PV installations have fallen over the last 10 years due to increased demand. In 2014, installation prices were at €1.03/watt, with the panels themselves costing €0.56/watt (ISEA, 2014). A $1m^2$ panel will have a max output rating of approximately 0.25 kWp, depending on cell type and manufacturer. As mentioned at the beginning of this chapter, there is no feed-in-tariff available for small renewable electricity generators, and therefore the installation should be sized to the daytime load so that all energy is used within the building. This limits the size of installations in some cases, unless a battery system is installed to store the energy to use for night time demands, but this can add significantly to the costs.

Solar thermal collectors, which produce hot water rather than electricity, come in two types: flat plate and evacuated tube, where flat plate collectors are designed so they can be incorporated into the roof rather than being installed on the roof and the evacuated tubes are on-roof installations only. The tubes allow approximately 20% higher energy yield per m^2 roof space than flat plate collectors. The heat is most often used for hot water demands, but is in some cases used for space heating where low temperature space heating is sufficient. A typical household installation will provide approximately 50-60% of the yearly hot water demand, depending on the roof space available. Around $1m^2$ of solar thermal collectors per person is a rough guide to the size of installation required per household (SEAI, 2010). SEAI estimates costs of between €800 and €1300 per m^2, and it currently offers grants of €1,200 towards home solar heating installations. Solar thermal can be a more economical choice and a better use of roof space over solar PV for households with little or no daytime occupancy, as the hot water will store in the insulated hot water tanks for use in mornings and evenings. Heating is one of the biggest reasons for fossil fuel use in buildings in Fingal, and off-setting this energy with renewable sources would reduce this dependence and reduce costs for homeowners.

Bioenergy Resources

Biomass is any organic material, like wood or plants, biofuels are liquid fuels made from the processing of biomass, and biogas is gas fuel extracted from the organic breakdown of biomass (anaerobic digestion). All energy derived from these sources is called bioenergy. Since organic material can be regrown, this

[15] Some houses will not have any south facing roof space, while others will have space for more than $1m^2$ of south facing PV panels. Apartment complexes could also install roof-top panels.

energy is a form of renewable energy. Like any other fuel, biomass, biogas and biofuels can be transported to be used in any location. For sustainability reasons, the bioenergy sources should be sourced as close to the point of use as possible, in order to lower the life-cycle energy.

With Ireland's large agricultural sector, there is a vast resource of farm waste that can be used for production of bioenergy. Rural areas are also ideal for growing bioenergy crops such as willow and miscanthus. The resources for growth or recycling of organic material in Fingal are high, with a considerable agricultural and horticultural industry present, as previously detailed.

The map in Figure 48 shows the suitability of land for miscanthus, oil seed, reed canary grass and willow growth. The purple area is all land which is unavailable, primarily located in the built up urban and residential areas in Fingal, including Balbriggan, Blanchardstown, Donabate and Howth. The vast majority of Fingal, however is deemed to have a high suitability for growing energy crops.

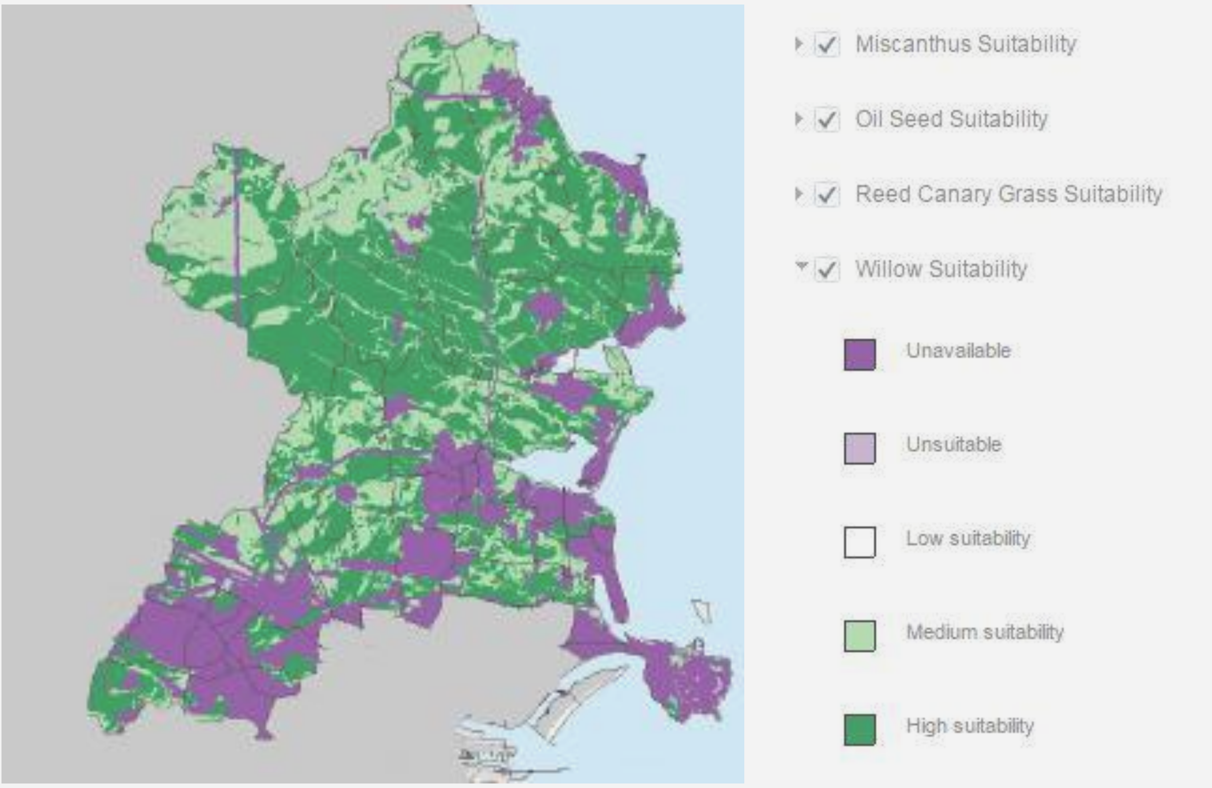

Figure 48 : Map showing the suitability of various bioenergy crops in Fingal

Despite the vast potential for energy crop growth in Fingal, Spring Oil Seed Rape is the only energy crop grown in the county. Reasons for this include competition for land with food growth and animal grazing.

Currently, the biggest renewable energy source used in Fingal is biomass. Biomass fired CHP units and boilers are widely used in commercial applications. There is a 1.2MW wood-pellet boiler at Charlestown Shopping Centre and other biomass boilers are found mainly in hotel and leisure businesses. Because biomass can be used in boilers just like any other fuel, it can easily be incorporated into existing wet heating systems. Like oil, the fuel must also be delivered in bulk and stored, so the only limiting factor is storage space and delivery access.

Even at a smaller scale, replacing open fires with wood burning or wood-pellet stoves will greatly increase efficiency and reduce costs and fossil fuel use. Wood logs are widely available and sold in many local grocery stores and petrol stations.

Heat Pumps and CHP

Although not specifically renewable technologies and not always reliant on the local resources, both heat pumps and CHP plants can use renewable fuels and have much higher efficiencies than traditional alternatives. Heat pumps use a low grade heat source, such as that discussed earlier from shallow geothermal sources, and increase the temperature through a compressor, operating on the same principle as a refrigerator. Depending on the input temperature, the heat pump will produce 3 kWh of heat for every 1 kWh of electricity input (a coefficient of performance (COP) of 3).

There are air, ground and water source heat pump technologies. Air source uses the ambient air temperature, ground source uses the solar heat emitted and stored in the earth, and water source uses solar heat stored in lake, river or sea water. Typically, ground and water sources will have a higher and steadier temperature than air source temperatures in winter, when heat is most required, and because of this, will generally have higher seasonal performance factors. Air source heat pumps can be installed in any location, are relatively low-cost to install, and have gained popularity in households with low heating needs. They are often used in combination with CHP plants to extract useful heat from flue gases. Ground source heat pumps need either deep bore holes to be drilled vertically or lay horizontal piping over a much larger space but at a much shallower level. The drilling of boreholes is a much more expensive installation, but can yield higher temperatures and may be the only option if there is no space for a horizontal pipe installation. Water source heat pumps will need a nearby or onsite water source which can be diverted for use in the heat pump and returned to the source. All heat pumps are run on electricity, and the costs should be weighed up and compared to other renewable heating solutions with low or no running costs. Heat pumps are best suited to low-energy housing and in combination with other renewable solutions like solar thermal.

CHP plants are a highly efficient power production plant, which utilises the heat produced in the process of electrical generation. In traditional electricity generation, the efficiencies are as low 40%, with much of the energy lost in the form of waste heat. By utilising this waste heat, CHP units can achieve efficiencies of more than 80%. In order for this to be a suitable energy solution, there needs to be a heating demand as well an electrical demand at the same or a nearby location. A CHP plant will produce nearly twice as many kWh of heat as electricity. CHP units are commonly found in hotels and leisure centres as these facilities have both electricity and heat demands onsite. CHP units are ideal production units for DH systems as they can offset the cost of heat production by selling the electricity to the grid. There are currently incentives and feed-in tariffs supporting high efficiency and renewable CHP.

In order to be feasible, a CHP requires a significant level of local heat demand. In this sense, the high energy demanding commercial glasshouses would provide excellent customers. A possible danger to this is that these businesses are not as reliable long term customers as, for instance municipality-owned buildings. However, the high consuming glasshouses near Swords and Rush are each located close to growing residential and commercial populations.

The renewable resources outlined above give an idea of the types of resources available in Fingal and an indication of how suitable each technology is in this area. Reducing demand through energy efficiency is always a priority, and only then should the use of renewable resources be considered to meet remaining energy demand. Waste heat is not a renewable source, but is a source of heat which is currently lost to the atmosphere and its potential to be utilised has not yet been fully explored. A full assessment of the heat currently going to waste from industrial and manufacturing processes in the county is recommended.

Conclusion

This SEDA has identified the location of electricity and heat demands throughout Fingal County. This gives planners the tools to become involved in how Fingal uses energy in the future and begin to integrate energy planning and spatial planning practices. For the first time, this SEDA has been able to identify specific priority locations for energy efficiency and sustainable energy solutions. This enables a more efficient and direct approach to implementing energy action plans.

In the residential sector, areas with the highest energy use have been identified, and also, importantly, areas most at risk of energy poverty. Targeting these areas first puts Fingal on the path to effectively reducing the energy demand in the residential sector, which is the largest energy consuming sector in the county. Residential areas which have high levels of electricity and electrical heating consumption can be targeted for upgrades to high-efficiency electrical heating systems and renewable electricity sources to offset their use.

Areas that are an ideal match for DH systems are highlighted through the mapping of heat demand densities. The areas of highest heat densities are the strongest candidates for first phase development of a DH system which would drastically and effectively lower the county's energy demand and fossil fuel use in the heating sector. The potential anchor loads and sources identified could be key stakeholders in the development of such systems.

Clusters of large commercial sector energy users identified can work together to reduce their energy demands and costs through projects which can capitalise on economies of scale. Creation of commercial sector energy groups or cooperatives can create knowledge sharing and help realise ambitious energy projects which may not be as economical or practical on an individual SME level.

This SEDA can now be built upon to create a strategic evidence-based energy plan for the county region, which outlines a number of energy mix scenarios for the area based on evidence gathered on demand and resources.

Further analysis of potential local sustainable resources is recommended so these energy resources can begin to be quantified and located, and then best matched with the demands already identified. Quantifying large sources of industrial waste heat should be prioritised in this resource analysis, as it is potentially a very low cost heat source which is currently going to waste. With solar PV being a very suitable RE source in Fingal, mapping and quantifying the solar resource space available is also a priority in terms of local RE electricity production. Location of planned future developments and their estimated energy use should be analysed further as these developments can be used to influence the energy use of existing surrounding buildings, particularly through shared heating systems.

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Acknowledgements

Codema would like to thank the Central Statistics Office, the Valuation Office and Dún Laoghaire-Rathdown County Council, in particular Sarah Cassidy, Energy Officer, for the invaluable data they provided for the completion of this work.

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