National Comprehensive Assessment of the Potential for Combined Heat and Power and District Heating and Cooling in the UK

Report for DECC

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Executive Summary

Introduction

This document has two related purposes; the first is to fulfil a legal requirement on all EU Member States to undertake a ***National Comprehensive Assessment*** (NCA) to establish the technical and socially cost-effective potential for **high-efficiency cogeneration** (combined heat and power, CHP) and **efficient district heating and cooling** (DHC). This requirement is set out in the Directive 2012/27/EU on energy efficiency (EED or the Directive); specifically in Article 14, which concerns the *Promotion of efficiency in heating and cooling*.

The second purpose is to help the UK in its overall heat policy development. There are two important caveats to this purpose:

- In the UK, heat is a devolved matter in Scotland and Northern Ireland. For Wales, although heat policy is a non-devolved matter, the encouragement of energy efficiency, other than by prohibition or regulation, is devolved. Scotland and Northern Ireland are responsible for developing their own heat policies;
- The definitions and methodologies for carrying out this assessment are specified in the Directive and its guidance notes, and are not always consistent with other existing methodologies. This is the case for example in the way in which the "social cost-benefit analysis" has been carried out. The findings in this report should be treated with caution and interpreted accordingly. For this reason, the report sets out in some detail the methodologies used, under the terms of the Directive, to provide maximum transparency and to provide context for why some of the projections and analysis in this document depart from other studies, including government and academic studies.

Methodology

Undertaking the "national comprehensive assessment" has involved determining the spatial distribution of the heat and cooling consumption of all sectors of the UK economy based on 2012 data, and projecting what these might be in 2025. The resolution of the underlying analysis is essentially at the level of the approximately 29 million buildings in the UK. The spatial heat and cooling data has been used to generate maps of heating and cooling consumption density, which also show the location of existing CHP plants and district heating, and potential sources of recoverable heat including power stations, waste incinerators and industrial facilities.

The heating solutions that have been assessed are split into three groups:

- conventional baseline solutions (gas and oil boilers, and resistive electrical heating), which are not considered to be "high-efficiency" under the Directive;
- individual high-efficiency solutions, i.e. those serving individual buildings/facilities; and
- district heating high-efficiency solutions, serving multiple buildings/facilities.

From the heat consumption and other availability information, "technical potentials" have been determined for selected high-efficiency and low carbon heat supply technology options, including high-efficiency CHP, micro-CHP and efficient district heating as required by the Directive. The technical potential for each technology is assessed independently of the alternatives. This potential is constrained by practical technical considerations but not by economic or commercial constraints. This "bottom-up" approach has been taken in respect of heating, but not of cooling.

In respect of cooling there are no existing national or regional demand data in the UK. Furthermore, since space cooling is largely elective in the UK, broad assumptions have had to be made to obtain estimated averages for cooling consumptions across postcode areas. It has therefore not been possible to assess the potential for high-efficiency cooling solutions with any confidence due to the lack of data at sufficient resolution.

The "socially cost-effective" potential of each solution has then been determined through cost-benefit analysis, with technically feasible options competing against each other and against conventional heating solutions on the basis of Net Present Value.

This assessment has been undertaken in line with the guidance set out in the HM Treasury Green Book and the supplementary guidance on valuing carbon emissions, energy savings and air quality improvements. The social cost-effectiveness relates to cost and benefits for society as a whole and is not an assessment of the commercial viability or otherwise of the heating solutions. Specifically the cost-benefit analysis has employed a social time preference rate of 3.5% to discount cash flows to present values, with cash-flow lines for:

- capital costs;
- fixed and variable operating costs;
- long-run variable costs (LRVC) of energy;
- air quality damage costs;
- costs of carbon; and
- cost of finance, which captures the element of risk for the capital investment in infrastructure.

The cost-benefit analysis does not include the impact of any current or future policies to support specific technologies or fuels, including the £300m of funding to support heat network projects announced by the Chancellor as part of the 25 November 2015 Spending Review.

Limitations

A national level analysis of this nature is subject to significant uncertainty. A strength of the modelling is that it has taken, as far as possible, a building by building approach, but inevitably there are limits to the quality of information at this level, such as building type, size, and heat demand profile. Striving for accuracy results in greater complexity; even with perfect information, there are practical limits to the level of detail with which a model can reasonably cope.

Where data has not been available or is of insufficient quality, simplifying assumptions have been made. Parameters such as capital and operating costs have to be simplified to what is considered 'typical' from the evidence available. As a result, the modelling analysis cannot fully capture the local conditions and distributional variations in costs and benefits. All results in this assessment should therefore be taken as purely indicative.

To deal with the inevitable uncertainties, the cost-benefit analysis has been undertaken under a range of scenarios (sensitivities) to determine the impact of assumptions regarding capital and maintenance costs, energy prices, finance costs and carbon prices.

A further limitation is that district heating systems have mainly been modelled with only a single heating technology rather than a mixture of heat sources, which is likely to be the case with many actual schemes. Schemes have been modelled at two different scales, but in reality there will be a significant number of possible sizes, configurations and technologies. Furthermore, only a limited set of technologies were considered; essentially those for which there is sufficient evidence of cost and performance parameters. For practical reasons therefore this study could not capture all possible solutions, particularly in respect of district heating configurations. This means that there is likely to be further cost-effective potential for high-efficiency solutions. Furthermore, the results of the study cannot be used to judge the viability of specific prospective schemes.

Results

Technical potentials

The technical potentials of the high-efficiency solutions have been calculated independently of each other with no reference to economic factors. The technical potential of a particular solution therefore represents a maximum technically possible deployment of the technology irrespective of costs and is expressed in terawatt hours (TWh) of heat that could be provided by that technology in the current circumstances and without policy intervention. The potentials are based on 2012 UK heat consumptions, derived from various sources.

The differences in technical potential arise because particular technologies cannot be used in certain circumstances, including building type/size, fuel availability and air quality restrictions. In addition for district heating the modelling was limited to areas above a threshold of building density (a plot ratio of at least 0.3). One of the simplifying assumptions in the modelling was that district heating would not provide heat for industrial process use as generally higher grades of heat are needed by industry; in the table district heating potential has been allocated across the commercial, pubic and residential sectors.

UK technical potentials for high-efficiency solutions, TWh of heat output pa.

<table>
<tr><th colspan="2">High-efficiency heating solutions</th><th>Total

TWh pa</th><th>Industry (incl. agriculture)

TWh pa</th><th>Commercial Services

TWh pa</th><th>Public Services

TWh pa</th><th>Residential

TWh pa</th></tr>
<tr><td rowspan="7">Individual</td><td>Gas CHP + gas boilers</td><td>401</td><td>112</td><td>20</td><td>25</td><td>244</td></tr>
<tr><td>Biomass CHP + gas boilers</td><td>46</td><td>38</td><td>2</td><td>6</td><td></td></tr>
<tr><td>Biomass boilers</td><td>167</td><td>39</td><td>7</td><td>9</td><td>112</td></tr>
<tr><td>Air to water heat pumps</td><td>334</td><td></td><td>19</td><td>23</td><td>291</td></tr>
<tr><td>Ground source heat pumps</td><td>267</td><td></td><td>19</td><td>23</td><td>225</td></tr>
<tr><td>Solar thermal + gas boilers</td><td>322</td><td></td><td>19</td><td>23</td><td>280</td></tr>
<tr><td>Solar thermal + biomass boilers</td><td>160</td><td></td><td>7</td><td>9</td><td>144</td></tr>
<tr><td rowspan="8">District heating</td><td>Gas CHP + gas boilers</td><td>276</td><td></td><td colspan="3">276</td></tr>
<tr><td>Biomass CHP + gas boilers</td><td>276</td><td></td><td colspan="3">276</td></tr>
<tr><td>Biomass boiler</td><td>276</td><td></td><td colspan="3">276</td></tr>
<tr><td>Ground source heat pumps</td><td>276</td><td></td><td colspan="3">276</td></tr>
<tr><td>Water source heat pumps</td><td>114</td><td></td><td colspan="3">114</td></tr>
<tr><td>Power station heat</td><td>46</td><td></td><td colspan="3">46</td></tr>
<tr><td>Waste incinerator heat</td><td>3</td><td></td><td colspan="3">3</td></tr>
<tr><td>Industrial waste heat</td><td>3</td><td></td><td colspan="3">3</td></tr>
</table>

The technical potential for the use of waste heat sources (power stations, waste incinerators and industrial waste heat) is restrained by the availability of heat loads in proximity to the sources. A 15 km radius was assumed as a practical limit for transporting the heat and only directly usable grades of heat have been considered for district heating serving commercial, public and domestic heat loads. Further technical potential could be realised through the use of heat pumps to increase the grade of the waste heat. No account has been taken in this study of the possible use of industrial waste heat on-site or by other nearby industrial sites. An Element Energy led study for DECC published in 2014[1] investigated the potential for recovering and using surplus heat from industry, identifying a technical potential of 7 TWh pa for on-site use and 3 TWh pa for use by other nearby industrial sites.

Social cost-effectiveness potentials

"Social cost-effectiveness" relates to cost and benefits for society as a whole and is not an assessment of the viability or otherwise of each heating solution. For comparative and illustrative purposes, three scenarios have been modelled:

i) At one extreme, a scenario where there is no government policy around de-risking investments in infrastructure, and with IAG 2014 toolkit[2] central scenario carbon prices ("full financing costs").

ii) At the other extreme, a scenario where the cost of securing the necessary finance is set at zero; in other words a totally de-risked capital-raising scenario and with IAG central scenario carbon prices ("zero financing costs").

iii) A scenario with a very high carbon price of £500/tCO_2 for all years and the same assumption as i) for cost of capital ("extreme carbon price").

Energy prices, capital and operating costs are kept constant through all scenarios. All of the scenarios assume that all technologies are replaced in one go in 2015.

[1] https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry
[2] UK Government's Inter-Departmental Analysts' Group (IAG) on Energy and Climate Change, 2014 toolkit (https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal)

Cost-benefit analysis scenario summary

Variable \ Scenario	i) Full financing costs	ii) Zero financing costs	iii) Extreme carbon price
Cost of finance	15% for industry, 10% for non-industrial sectors	0% all sectors	15% for industry, 10% for non-industrial sectors
Energy prices	IAG long-run variable cost (LRVC) of energy supply, central values	IAG long-run variable cost (LRVC) of energy supply, central values	IAG long-run variable cost (LRVC) of energy supply, central values
Carbon prices	IAG carbon prices traded and non-traded, central values	IAG carbon prices traded and non-traded, central values	£500 per tonne of CO_2
Capex and opex	UK best evidence values for each technology	UK best evidence values for each technology	UK best evidence values for each technology

This sensitivity analysis gives the following results:

Summary of UK cost-effective potential of high-efficiency solutions by scenario, TWh of heat output pa.

Solution \ Scenario	i) Full financing costs TWh pa	ii) Zero financing costs TWh pa	iii) Extreme carbon price TWh pa
High-efficiency, total	**131**	**314**	**358**
Individual	*116*	*128*	*200*
District heating	*15*	*186*	*158*
Conventional, total	**334**	**168**	**120**
Total heat output	**465**	**481**	**477**

This sensitivity testing shows that under scenario i) most total heat output continues to come from fossil fuel baseline heat (conventional heating technologies), but in scenarios ii) and iii) more heat comes from high-efficiency heating than conventional technologies, with the extreme carbon price bringing on more individual high-efficiency heating, and the zero cost of finance bringing on more district heating networks heating. These results illustrate the potential effectiveness of two levers that could be employed to pull forward high-efficiency heating, one involving de-risking capital investment in high efficiency heating solutions and the other introducing mechanisms for cost equalisation dependent on the carbon content of the heat.

Data sources: copyright and database rights

This report presents results, including maps that contain or are derived data of the following:

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1 Introduction

This report presents the methodology employed and the outcomes of the UK's comprehensive assessment, undertaken by Ricardo Energy & Environment on behalf of the Department for Energy and Climate Change (DECC) and the devolved governments of the UK in accordance with Article 14 of the Energy Efficiency Directive 2012/27/EU.

1.1 Background

In October 2012 the European Union adopted the Directive 2012/27/EU on energy efficiency[3] (EED or the Directive). This established a common framework of measures for the promotion of energy efficiency within the EU as part of the strategy to meet the 2020 energy efficiency target of a 20% reduction in primary energy consumption compared to projections.

Article 14 of the Directive concerns the *Promotion of efficiency in heating and cooling*, with Article 14(1) requiring that Member States undertake a ***National Comprehensive Assessment*** (NCA) to establish the potential for **high-efficiency cogeneration** (combined heat and power (CHP)) and **efficient district heating and cooling** (DHC), both of which have specific meanings set out in the EED.

High-efficiency cogeneration is defined against specific EU reference values for the efficiency of the separate production of heat and electricity, (i.e. via the use of boilers and of power stations with no heat recovery) and meets the following criteria:

- provides primary energy savings of at least 10% compared with EU efficiency reference values for the separate production of heat and electricity;
- or for small-scale and micro-cogeneration units, provides any primary energy savings.

Efficient district heating and cooling refers to the sources of heat/cooling generation, not the efficiency of the distribution infrastructure (which is affected by levels of pipe insulation, flow and return temperatures, etc.). District heating is considered as 'efficient' if it uses at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat.

The requirement for NCAs reflects the importance across the EU of the use of primary energy for the generation of heat for space and hot water heating, industrial processes and cooling. In the UK nearly half the energy we use is for heating of one sort or another.

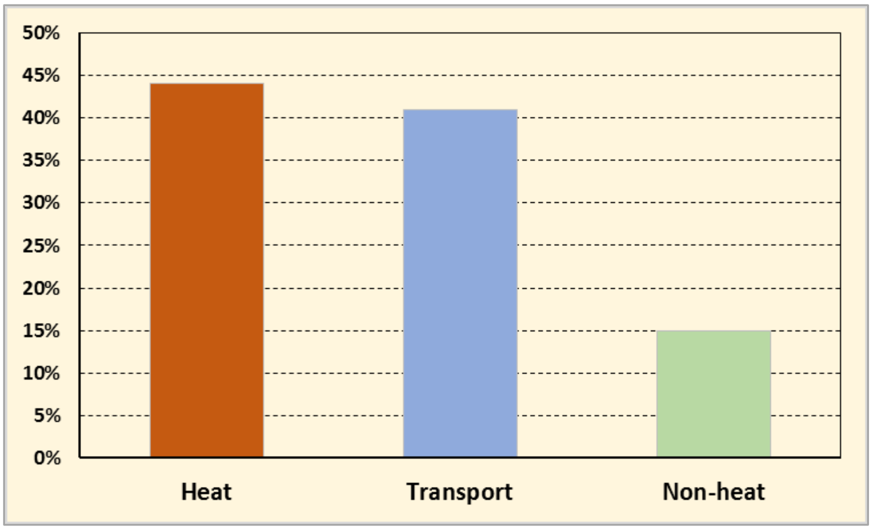

Figure 1.1: UK split of energy use for heat, transport and non-heat (2011)[4]

[3] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

[4] The Future of Heating: Meeting the challenge, DECC March 2013 (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf)

As a consequence of a high heating demand, a low requirement for cooling, and access to North Sea gas in recent decades, the UK has developed into the world's number one market for gas boilers. Natural and mechanical ventilation rather than air conditioning are the main forms of cooling in the domestic sector and parts of the commercial sector. Where some countries have been developing heat networks and renewable heating in response to concerns about price and security of supply of imported fossil fuels, the UK's low penetration of these technologies is a direct consequence of ample supplies of low cost natural gas distributed nationally. This report does not assume any change to gas availability over the period of analysis.

1.2 NCA requirements

Each Member State's NCA has to be notified to the Commission by 31st December 2015 and must include the information set out in Annex VIII to the EED, summarised below.

Box 1.1: Summary of EED Annex VIII requirements

The comprehensive assessment of national heating and cooling potentials shall include:

a. a description of heating and cooling demand[5];
b. a forecast of how this demand will change in the next 10 years;
c. a heat map of the national territory;
d. identification of the heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration, and by district heating and cooling;
e. identification of the potential for additional high-efficiency cogeneration, including from the refurbishment of existing and the construction of new generation and industrial installations or other facilities generating waste heat;
f. identification of energy efficiency potentials of district heating and cooling infrastructure;
g. strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potentials;
h. the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC;
i. an estimate of the primary energy to be saved; and
j. an estimate of public support measures to heating and cooling.

Article 14(3) specifies that the assessment must include a cost-benefit analysis (CBA), in accordance with Part 1 of Annex IX of the EED, in order to identify the most resource and cost-effective solutions to meeting the heating and cooling needs identified in the NCA.

Box 1.2: Summary of EED Annex IX requirements

Cost-benefit analysis shall include an economic analysis covering socio-economic and environmental factors. The cost-benefit analysis shall include the following steps and considerations:

a. Establishment of a system boundary and boundaries of suitable well-defined geographical areas;
b. An integrated approach to demand and supply options within each defined geographical boundary;
c. Construction of a baseline to provide a reference point against which alternatives are evaluated;
d. Identification and evaluation of high-efficiency alternatives to the baseline;

[5] The Directive uses the term 'demand', which can mean instantaneous energy demand in units of power such as kW, or energy consumption (or usage) over a period of time in units of energy such as kWh. Demand in the EED generally refers to annual energy consumption.

e. Calculation of cost-benefit in terms of Net Present Value (NPV), incorporating comparison of long-term costs and benefits of the options;
f. Clear calculation and forecast of prices and other assumptions for the economic analysis, including external costs such as environmental and health effects;
g. Economic analysis that includes all relevant economic effects; and
h. Sensitivity analysis to test the impact of different assumptions.

1.3 Heating technologies

A range of heating technologies are referred to in this report, which fall into two categories, conventional and high-efficiency, that reflect the Directive's requirements for what are considered to be high-efficiency solutions. The conventional solutions comprise gas boilers, oil boilers and electric resistive heating. It is important to stress that '*high-efficiency*' gas or oil boilers are not considered to be high-efficiency heating solutions for the purposes of the NCA.

In the following sections short descriptions of the relevant conventional and high-efficiency solutions are given outlining how they work, potential benefits in terms of energy efficiency and carbon savings and some of the limitations/issues surrounding their use.

1.3.1 Conventional heating solutions

In excess of 70% of heating in the UK is provided by conventional **oil and gas boilers**. These raise heat in the form of hot water or steam, which is distributed via pipework to the points of the heat demand, which could be radiators and a hot water storage vessel in a home, air handling units in a commercial property, or a manufacturing process at an industrial site. Modern systems can be very efficient if designed, operated and maintained well. Many hot water boilers for domestic and commercial buildings are now of the condensing type whereby heat otherwise lost is recovered by condensing the water vapour in the flue gases. However, whilst laboratory tests have shown that modern condensing boilers can attain efficiencies of around 90%, field trials[6] show lower efficiencies are frequently achieved in practice.

Electric resistive heating is still employed in around 10% of domestic properties in the UK, electric storage heaters being the most common. As using electricity is the most expensive and carbon-intensive heating fuel available in the UK, these make use of off-peak electricity to heat a thermal store within the heater, which then releases energy over the course of the next day. The storage medium, normally ceramic or bricks (to provide reasonably high energy storage densities) is heated to more than 200 degrees centigrade using electric elements. Whilst such electric resistance heating is a mature technology, modern storage units do provide more usable heat than in the past through better controls, increased levels of insulation that retain more heat, and convector fans that can heat a room up faster.

Whilst radiators or storage heaters are the main means of providing space heating in the UK, there are a number of alternative technologies can be used alongside or instead of, such as, oil filled radiators open, electric and gas fires to provide the required level of heating.

1.3.2 High-efficiency heating solutions

The successful deployment of high-efficiency heating technologies often requires the use of more than one technology due to differing characteristics of technologies and inter-dependence between them. Frequently the benefits are maximised when the technologies are used together within a wider energy network.

Combined Heat and Power (CHP) is the simultaneous generation of heat and power in a single process. The power output is usually electricity, but can be mechanical power. Heat outputs can include steam, hot water or hot air for process heating, space heating or be used to generate cooling via absorption chilling. CHP that produces electricity, heat and cooling is termed 'tri-generation'. CHP schemes are typically much smaller than conventional power stations, and sized to meet customers' heat demands. Schemes vary in size from tens of kW to hundreds of MW of electrical capacity, and

[6] Gastec, 2009, In situ monitoring of efficiencies of condensing boilers and use of secondary heating

can be found in building such as hospitals and universities, or on industrial sites (for example in the paper and chemicals sectors) or supplying a district heating scheme.

CHP is well established in the UK principally as a gas-fired technology, though renewable fuelled schemes are becoming increasingly common, and there is significant potential for additional capacity. Provided there is a simultaneous demand for both heat and power, CHP can deliver energy and carbon savings of up to 30% by reducing the energy lost as waste heat compared to separate power and heat generation from the same fuel.

Electrical generation efficiency generally reduces as more heat is extracted, but this is more than made up for by the useful heat supplied. The UK has around 6,000 MWe of CHP installed at the present time which is estimated to have saved around 7.55 $MtCO_2$ (million tonnes of carbon dioxide) in 2014[7].

CHP is capital intensive and usually operates alongside supporting boiler plant, including **biomass boilers** that burn organic material (usually wood chips, logs or pellets) to generate heat that is typically used to produce hot water or steam for process or space heating, or domestic hot water.

Biomass boiler have the potential to displace those using fossil fuels within the public, industrial/commercial and domestic sectors delivering significant CO_2 emission savings[8] . However, such fuel is more difficult to transport, handle and store when compared to natural gas. Combustion of biomass is not necessarily a low pollution option as it gives rise to emissions including particulates, NO_x, and CO at levels that may prevent the use of these boilers in certain areas if scrubbers and filters are not fitted. This adds to costs, but not necessarily prohibitively so, particularly where serving larger heat demands such as district heating networks.

Heat pumps play an important role in helping to increase energy efficiency and the deployment of low carbon energy (e.g. via air source heat pumps replacing domestic heating systems running on electric, oil and solid fuel) and their long term strategic value was highlighted in the Government's framework for low carbon heat[9]. They work by transferring low temperature heat from the ambient **air**, **water** or **ground** and raising it to a higher temperature by way of a refrigeration cycle, using only a relatively small amount of energy (usually electricity) to drive the refrigerant compressor in doing so.

Performance of a heat pump is judged by the ratio of heating or cooling provided to power consumed giving a coefficient of performance (COP). The Government's non-domestic Renewable Heat Incentive (RHI) scheme[10] currently requires heat pumps to meet a minimum COP of 2.9 and also to operate with a design seasonal performance factor (SPF) of at least 2.5, the latter being defined as "the ratio of [the heat pump's] heat output to electricity input expressed as an average over a year". Thus for a SPF of 2.5, on average for every 1kWh of electricity used, the heat pump will generate 2.5 kWh of heat.

A heat pump operating with a SPF just above 2.5, would consume less fuel than a condensing boiler in the UK[11]. Thus at around a SPF of 2.5, a heat pump's carbon efficiency approximates to that of a gas boiler and with decarbonisation of the electricity system, heat pumps have the potential to be one of the lowest carbon intensity options for space heating[12].

Another heating option is a **solar thermal** system, using heat from the sun via solar collectors to warm hot water for a variety of uses. These can include space heating (via radiators and underfloor heating), heating water for direct use or indirectly for cooling (through absorption chillers) and for a range of specific processes. Typically however, they are used to provide a proportion of a building's hot water requirements and need to be supplemented by other forms of heating. An Energy Saving Trust study that trialled solar water heating systems to investigate how actual systems perform in real homes in the UK and the Republic of Ireland indicated that typical carbon savings in the order of 230 kg/year were achievable through replacing gas with solar heating[13].

District heating and cooling enables the centralised provision of heat to a number of buildings, premises, sites or other users. This is typically for the purpose of providing hot water, space heating or

[7] Combined heat and power: Chapter 7, Digest of United Kingdom Energy Statistics (DUKES) https://www.gov.uk/government/statistics/combined-heat-and-power-chapter-7-digest-of-united-kingdom-energy-statistics-dukes

[8] http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

[10] https://www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi/eligibility-non-domestic-rhi

[11] Staffell, I et al, 2012, Energy Environ Sci, 5, 9291-9306

[12] http://researchbriefings.files.parliament.uk/documents/POST-PN-426/POST-PN-426.pdf

[13] http://www.goodenergy.co.uk/media/BAhbBlsHOgZmIh00ZTk2YWEzZGUzNDU5YjRiMWIwMDBlMTI/i.3471_EST_SolarThermalWaterReport_Web.pdf?suffix=.pdf

cooling (in the form of chilled water via absorption chilling) but can include the provision of process steam. The provision of cooling can enable plant to operate more cost-efficiently by creating additional demand for heat in the summer.

Given the high capital costs of the distribution infrastructure, district heating tends to be economic only when relatively low cost sources of heat can be used, such as from CHP. CHP plants serving district heating are nearly always supplemented by top-up boilers so that the CHP can be sized such that it will operate at a sufficiently high load factor to be economic. Where CHP and/or boilers are fired on biomass there are additional costs compared with gas-fired plant associated with flue gas emissions abatement, including of particulates. With the economies of scale of district heating, these costs have less impact on project economics compared with smaller biomass fired equipment, though local restrictions and requirements have to be taken into account.

Large scale heat pumps (particularly water source) are increasingly being used to supply district heating. Heat networks also facilitate sources of heat to be utilised that would otherwise not be used or would be difficult to use such as waste heat, unprocessed biomass, geothermal, off-takes from power stations and energy from waste plants. Industrial waste heat, for example, which can be recovered and re-used in a variety of ways including within the same facility or in nearby industrial plants, can also be utilised via heat networks where lower temperatures are required. As it is surplus heat, it is effectively a zero carbon energy source. An Element Energy led study for DECC published in 2014[14] investigated the potential for recovering and using surplus heat from industry, identifying a technical potential of 7 TWh pa for on-site use and 3 TWh pa for use by other nearby industrial sites.

There are potentially significant carbon, as well as energy efficiency savings from moving to district heating, a Poyry led study [15] on behalf of DECC published in 2009 calculated that a district heating network covering a quarter of a million households may save between 0.25 and 1.25 $MtCO_2$ annually relative to conventional heating systems, dependent on the fuel used and the carbon intensity of centralised electricity production assumed. Their analysis also suggests that "where district heating networks can achieve high penetration (in the region of 80%) in a built up area, the carbon abatement costs of district heating options can be better than the most cost-effective stand-alone renewable technology".

1.4 Structure of this report

This report presents the methodology and the results of the UK's comprehensive assessment. The structure of this document is as follows:

Section 1 provides an introduction and context to the study

Section 2 provides a high level description of the study methodology, with further details provided in Appendix 2.

Section 3 presents the results of the modelling and commentary on the results.

Section 4 considers current relevant policy measures in the UK and summarises progress on high-efficiency CHP deployment under the Cogeneration Directive 2004/8/EC.

[14] https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

[15] http://www.poyry.co.uk/sites/www.poyry.uk/files/A_report_providing_a_technical_analysis_and_costing_of_DH_networks.pdf

2 Approach and methodology

This section provides a high-level description of the approach and methodology followed in undertaking the comprehensive assessment for the UK. Further details are provided in Appendix 2.

2.1 Overview

The comprehensive assessment has been undertaken in stages as described below and illustrated in Figure 2.1. These mirror the requirements of the Directive. The process has principally been realised via a bespoke model constructed in Microsoft Access and implemented in the form of a series of Microsoft SQL queries, with the data used being stored in a series of linked Access databases. Some elements of the initial modelling process were completed using geographic information system (GIS) software and the results imported into the model. Much of the pre-processing of data was undertaken in Microsoft Excel, though for practical reasons some pre-processing was undertaken within the Access model itself.

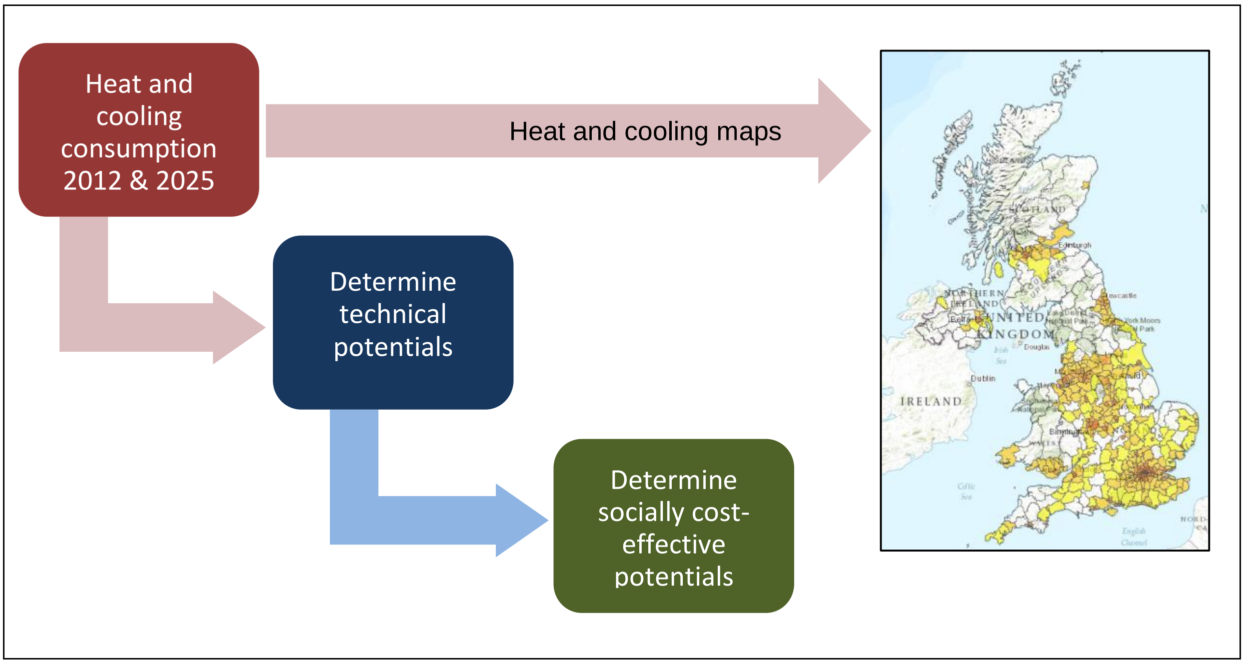

Figure 2.1: Comprehensive Assessment Approach

The figure above illustrates the main steps of the methodology employed, which are:

1. Extraction of data from the various input data sources to determine the “current” (taken as 2012 after a review of data availability) annual heat and cooling consumptions by geographic area across the UK.
2. Projection of those consumptions to 2025.
3. Generation of spatially defined data layers for the mapping of heat and cooling densities. Also of the locations of existing CHP plants, district heating schemes, power stations, waste incinerators and industrial sources of waste heat.
4. Specification of a baseline that comprises a simplified version of the current range of heat technologies deployed, representing a business as usual scenario.

   Assessment of the technical potential for high-efficiency heat supply solutions in two categories:

   a. **high-efficiency individual solutions** for satisfying the heat consumption of an individual building or site.
   b. **high-efficiency district heating (DH) solutions** for satisfying the aggregate heat consumption of a defined geographic area.

   The solutions modelled are described further in section 2.2.4.

The poor spatial resolution of cooling consumption data and the elective nature of comfort cooling in the UK has meant that it has not been possible to model district cooling solutions with sufficient confidence in the validity of the results.

5. Assessment of the socially cost-effective potential of the solutions via cost-benefit analysis. The cost-benefit analysis is from the perspective of society as a whole and so includes socio-economic and environmental factors.

2.2 Methodology steps in more detail

The following sections provide further detail on the assessment methodology. Each first presents a summary of the relevant guidance from the European Commission's guidance note on Article 14 of the EED[16].

The EED uses the term "*demand*" meaning energy consumption (or use); in this report, where appropriate, "*consumption*" is used to avoid any ambiguity with the other common use of '*demand'* to mean '*power'* (the rate of energy flow).

2.2.1 Current heating and cooling consumption

There are around 29 million properties in the UK with the vast majority currently served by individual heating systems, some by individual cooling plant, and a very small proportion (well below 500,000) by district heating and cooling (DHC) schemes.

Heating consumption

The annual heating consumption and the coordinates of each individual demand point (building, installation or existing district heating and cooling (DHC) scheme) were estimated based on a number of national statistical data sets and other available data sources (see Table 2.1). A base year of 2012 was selected after a review of the data available.

Table 2.1: Principal data sources for determining spatially defined heat consumptions

Data type	Source
Energy – national and sub-national statistics	Energy Consumption in the United Kingdom (ECUK) (National statistics on overall energy consumption in UK, broken down by sectors)[17].
	DECC sub-national statistics on the consumption of gas and electricity, 2012.
Energy – site specific	National Atmospheric Emissions Inventory (NAEI) data on fuel consumed by larger individual demand points.
	CHP Quality Assurance programme (CHPQA): heat generated and fuel consumed by existing CHP installations.
	DECC survey of district heating in the UK, 2014: heat generated by existing DH installations.
Energy – commercial buildings	Interdepartmental Business Register (IDBR) [18]: employment data used as a proxy for relative heat consumption of commercial buildings.
Energy - residential	2011 Census data on the type of central heating technology used by dwelling type.
	DECC's National Housing Model: heating fuel consumption data[19].

[16] SWD(2013) 449 final, Guidance note on Directive 2012/27/EU on energy efficiency, Article 14: Promotion of efficiency in heating and cooling http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0449&from=EN

[17] Energy Consumption in the United Kingdom' (ECUK) is an annual statistical publication by DECC that provides a comprehensive review of energy consumption and output since the 1970s https://www.gov.uk/government/collections/energy-consumption-in-the-uk

[18] http://www.ons.gov.uk/ons/about-ons/business-transparency/freedom-of-information/previous-foi-requests/business--industry-and-trade/interdepartmental-business-register/index.html

[19] DECC National Housing Model (NHM) (not published) estimates a typical heating fuel consumption for each type of dwelling and heating fuel. http://www.cse.org.uk/projects/view/1233

Data type	Source
Geographic (mapping)	Data on building locations (i.e. grid coordinates[20]) and floor areas[21].
Spatially defined heat consumption for Scotland	Scotland Heat Map data (updated October 2015).

The analysis thus involved processing and combining of data on:

- Fuel consumption at various spatial resolutions from individual sites to national level;
- Heating energy use;
- Employment statistics;
- Building co-ordinates.

For Scotland, the underlying data for the Scotland Heat Map was also integrated into the data sets.

The heat consumption has therefore been determined for each individual property in the UK. Unique Property Reference Numbers (UPRNs) have been used to identify individual properties and these have been linked to standard UK statistical geographies. The heat data therefore has a spatial as well as sectoral dimension.

Cooling consumption
Cooling in the context of the NCA has been taken as those requirements for cooling that could, at least in principle, be provided via district cooling. This means a chilled water flow temperature in the region of 4°C, which can be provided via absorption chilling plant driven by a supply of heat. This heat could originate as waste heat or be taken from a CHP installation facilitating a better CHP load factor and/or specification of a larger CHP system than would otherwise be the case.

The cooling loads considered in the NCA have therefore been limited to those that could be supplied by chilled water at a temperature ≥4°C for air conditioning and particular industrial processes. This excludes lower temperature refrigeration requirements, such as freezing and chilling in the food and drink industry. It has also been assumed that there are no space cooling requirements in the residential sector.

Unlike heating consumptions, there are no existing national or regional data on the demands for cooling in the UK. In order to estimate cooling consumption, a ratio of cooling to heating consumption was established for each activity (represented by a 5 digit SIC code) where space cooling is typically used. This was based on CIBSE Guide F[22] indicators for annual heating fuel and cooling electricity per square meter of floor area for different building types. As space cooling is largely elective in the UK, broad assumptions have had to be made as to the penetration of cooling in particular applications and the cooling consumptions averaged across postcode areas, meaning that there is much less confidence in the results in comparison with heating consumptions.

2.2.2 Projections of heating and cooling consumption in 2025

Each year DECC publishes updated energy projections (UEPs), analysing and projecting future energy use and greenhouse gas emissions in the UK.

These projections are based on assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables. The projections take account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made.

A general downward trend in final energy consumption (heating fuel and electricity) is anticipated over the next 10 years, except for agriculture (see Table 2.2 below) where a high growth in renewables is predicted.

[20] Each property is identified by a Unique Property Reference Number (UPRN)

[21] This was sourced from Ordinance Survey (OS) for Great Britain. For Northern Ireland (NI), similar data was obtained from Ordinance Survey Northern Ireland (OSNI) and the Department of Finance and Personnel's Land and Property Services LPS (NI).

[22] CIBSE Guide F: Energy Efficiency in Buildings, 2012 http://www.cibse.org/knowledge/cibse-guide/cibse-guide-f-energy-efficiency-in-buildings

Table 2.2: Total final energy consumption by sector, TWh pa

Sector	2012 TWh pa	2015 TWh pa	2025 TWh pa
Agriculture	10	13	19
Commercial services	160	153	130
Residential	508	480	447
Iron & steel	14	16	13
Other industry sectors	269	274	250
Public services	73	70	56
Total final energy consumption	**1,034**	**1,005**	**915**

Derived from UEP 2014 Annex F[23]

Totals may not equal sum due to rounding

The UEPs for 2014 were used to inflate/deflate the 2012 heat and cooling consumptions to 2015 and 2025 on the assumption that these will follow the same trends as final energy consumption.

For the domestic sector, the projections of heating and cooling consumptions have also taken account of the Department for Communities and Local Government (DCLG) projections of the growth in UK household numbers and historical rates for the demolition of dwellings.

2.2.3 Heat and cooling maps

The UK has a number of heat maps developed prior to the NCA:

- CHP development map (http://chptools.decc.gov.uk/developmentmap/)
- National heat map for England (http://tools.decc.gov.uk/nationalheatmap/)
- Scotland heat map (http://www.gov.scot/HeatMap)

The data for the existing England heat map has been reviewed but not used in the NCA, except for the water source heat capacity layers, which have been incorporated into the NCA model. The latest Scotland heat map data has been integrated with data for Scotland derived in the NCA exercise and this employed in both the mapping and modelling of potentials.

The data derived on the spatial distribution of the consumption of heating and of cooling throughout the UK have been used to calculate heat and cooling densities in MWh/km^2 for each Middle Layer Super Output Area (MSOA) for England & Wales, Intermediate Zone (IZ) in Scotland, and Ward in Northern Ireland; i.e. 9,602 discrete areas. This has resulted in separate data layers for heat and for cooling densities.

Subject to the commercial confidentiality of information for certain installations, data sets (layers) have also been established for existing demand and supply points:

- CHP plants;
- District heating and cooling schemes;
- Power stations;
- Waste incineration plants;
- Potential sources of waste heat from industry;
- Water source heat capacities (rivers, estuaries and coastal regions in England)

Heat and cooling maps have been produced by overlaying these data layers on to UK base layer maps using GIS software.

[23] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

2.2.4 Technical potentials for high-efficiency solutions

The baseline and high-efficiency solutions

The Directive refers to the technical potentials as "*the heating and cooling demand that could be satisfied by high-efficiency cogeneration and by district heating and cooling*", which as already noted have specific meanings set out in the EED.

High-efficiency cogeneration is defined against specific EU reference values for the efficiency of the separate production of heat and electricity, i.e. of boilers and of power stations with no heat recovery and meets the following criteria:

- provides primary energy savings of at least 10% compared with EU efficiency reference values for the separate production of heat and electricity;
- or for small-scale and micro-cogeneration units, provides any primary energy savings.

District heating is considered as 'efficient' if it uses at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat. District heating systems have therefore been modelled on the basis of being served either by CHP, biomass CHP, biomass boilers, heat pumps or sources of recoverable waste heat.

The heating solutions that have been assessed are split into three groups:

- conventional baseline solutions;
- individual high-efficiency solutions; and
- district heating high-efficiency solutions.

The baseline comprises a simplified version of the current range of heat technologies deployed and assumes that over time they will be replaced with similar technologies but with improved efficiencies. The baseline therefore is essentially a business as usual scenario and comprises individual boilers, electric heating, existing CHP and existing district heating. The baseline therefore consists mainly of conventional technologies (boilers and electric heating) plus some high-efficiency solutions in the form of existing CHP and district heating. There is therefore a degree of overlap between the baseline and high-efficiency solutions in respect of existing high-efficiency CHP and efficient district heating.

It is important to stress that 'high-efficiency' gas or oil boilers are not considered to be '*high-efficiency solutions*' for the purposes of the NCA, which are those listed in Table 2.4 below.

The top half of Table 2.3 shows the heating technologies chosen as being the most likely high-efficiency alternatives to the baseline for serving individual buildings or sites. Although not strictly a requirement of the Directive, certain renewable energy individual solutions have also been included as options in the modelling. Only electrically driven heat pumps have been considered in this study.

Table 2.3: High-efficiency solutions assessed

Solution type	Heating technology
Individual	Gas fired CHP with gas top-up boilers
	Biomass fired CHP with gas top-up boilers
	Biomass fired boilers
	Air to water heat pumps
	Ground source heat pumps
	Solar thermal with top-up gas or oil fired boiler
District heating	Gas fired CHP with gas top-up boilers
	Biomass fired CHP with gas top-up boilers
	Biomass fired boilers
	Ground source heat pumps
	Water source heat pumps (England only)
	Heat take-off from existing power stations
	Energy from existing waste plant heat
	Industrial waste heat from existing plants

The table also shows the technologies selected as being the most likely high-efficiency options for serving district heating systems. For each it has been assumed that thermal stores would be installed to even out the daily variation in heat load thus allowing reduced plant sizing and increased load factors resulting in improved viability.

The use of recoverable heat sources in district heating involves waste heat recovery or extraction from specific potential sources. The potential for the use of such sources is constrained by the quantity and quality of available heat, and their proximity to areas suitable for DH. The potential for the use of such heat has been limited to a 15 km radius from the source.

Water source heat pumps serving district heating have only been analysed for England since data on heat resource availability is currently not available for other parts of the UK[24]. If the area is on the coast or an estuary then the heat source is assumed to be unlimited; for rivers the heat capacity is that of the stretch of river within the area in question.

Technical potentials

The technical potentials of the heat supply solutions have been calculated independently of each other with no reference to economic factors. The technical potential of a particular solution therefore represents a maximum technically possible deployment of the technology irrespective of costs.

In addition to the annual heating consumption, the type of demand point (DH scheme, non-domestic sector or dwelling type) and the existing heating system and fuel type affect the technical potential for each solution. In modelling the technical potentials, the following simplifying restrictions on technology/property combinations have been employed, in part as a consequence of insufficient data quality:

- A lower size limit to screen out buildings with calculated heat consumptions below 4MWh pa which has been taken as the smallest practical heat load to be served by non-electric heating and so would typically not be suited to high-efficiency solutions. These comprise only about 0.5% of total heat consumption.
- Data on geographic availability of gas has proved to be inconsistent so a broad-brush assumption has been made that for dwellings where there is no gas supply within the postcode, micro-gas CHP cannot be installed. For all non-domestic buildings, it has been assumed that gas will be available and therefore individual gas CHP can be installed.
- Where individual dwellings or non-residential buildings are currently heated with electricity, they will continue to be heated with electricity. There is no such restriction for district heating systems.
- No individual domestic biomass boilers can be installed in smoke control zones. For district heating and non-domestic applications biomass plant (boilers and/or CHP) can be installed in smoke control zones as it is assumed that additional emissions abatement equipment is fitted; a capital cost adjustment has been made to account for this and the IAG oil air quality damage costs has been used instead of those for biomass; both of these adjustments affect the cost-effective rather than technical potential.
- No gas micro-CHP, gas boilers, biomass boilers, GSHPs or solar thermal will be installed in individual flats for practical and safety reasons. The available data is insufficient to distinguish between high-rise, low-rise and the conversion of houses into flats.
- No heat pumps, solar thermal systems or district heating schemes will serve industrial sites. There is insufficient data available on the grade of heat required by individual industrial sites; it has been assumed generally that the requirement will be for steam and so not amenable to these technologies.
- For waste heat from power stations, waste incinerators and industry, only directly usable grades of heat have been considered; the possible use of heat pumps to increase the grade of the waste heat was not included in the analysis. No account has been taken of the possible use of waste heat by other industrial sites since specific site by site information would be needed, including on the grades of heat required and the quantities thereof.

[24] http://tools.decc.gov.uk/en/content/cms/heatmap/user_guide/user_guide.aspx#section-14

Given the poor spatial resolution and low confidence in the cooling consumption data, modelling of the potential for district cooling solutions has not been undertaken as there would be insufficient confidence in the validity of the results.

2.2.5 Socially cost-effective potentials for high-efficiency solutions

The Directive refers to the cost-effective potentials as "*The potential for additional high-efficiency cogeneration and efficient district heating and cooling*". Annex IX requires that the cost-benefit analysis be undertaken in terms of net present value (NPV). Furthermore, the Directive requires the assessment of what is socially cost-effective, rather than that which would provide an investor with an acceptable commercial return; i.e. it needs to reflect the true socio-economic costs and benefits.

Approach

To meet these requirements the assessment has been undertaken in line with the guidance set out in the HM Treasury Green Book and the supplementary guidance on valuing carbon emissions, energy savings and air quality improvements provided by the UK Government's Inter-Departmental Analysts' Group (IAG) on Energy and Climate Change[25]. Specifically the cost-benefit analysis has employed:

- A discounted cash-flow and NPV approach, with cash-flow lines for:
  - capital costs;
  - fixed and variable operating costs;
  - energy costs;
  - air quality damage costs;
  - costs of carbon; and
  - the cost of finance.
- The HM Treasury Green Book[26] social time preference rate of 3.5% to discount cash flows to present values.

Capital costs are assumed to be spent in the year immediately preceding the asset becoming operational. The residual value of the assets at the end of the assessment period (2015 to 2030) is factored into the analysis (as a benefit) to take account of different technology lifetimes.

The energy costs used are long-run variable costs (LRVC) of energy, which represent the costs to society as a whole of energy supply and which exclude transfers between groups[27]. These and the air quality damage factors and carbon prices have been taken from the IAG's 2014 toolkit (IAG 2014).

Consistent with Green Book supplementary guidance, the cost of finance has also been included in the cost benefit analysis, socially discounted in the Net Present Value calculations. Amongst other things, the cost of finance represents compensation for risk and uncertainty. The costs of financing the capital expenditure are spread over the life of the asset.

IAG all-GHG carbon dioxide equivalent emissions factors have been used to determine emissions from the use of fuels and electricity, except for grid electricity displaced by CHP where values have been taken from bespoke natural gas CHP analysis commissioned by DECC to examine what type of electricity generation would be displaced if additional gas CHP was brought forward. [28]

The cost-benefit analysis does not include the impact of any current or future policies to support specific technologies or fuels, including energy/carbon taxation.

Solution selection

The cost-effective potentials have therefore been determined by undertaking a cost-benefit analysis of potential heat supply solutions, including the baseline solution for each heat demand point (or group of demand points for district heating) determining which solution has the best Net Present Value.

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[25] Interdepartmental Analysts' Group on Energy and Climate Change, 2014 Toolkit (https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal)

[26] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

[27] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360044/2014_Background_Documentation_to_DECC_HMT_Supplementary_Appraisal_Guidance.pdf (section 5)

[28] https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

Determination of cost-effective solutions

To determine the economic potential, the cost-effective solutions for each MSOA, IZ and Ward are determined by comparison of high-efficiency solutions with the baseline solutions following the following process:

1. For each MSOA (or equivalent) the NPVs for all technically suitable district heating solutions are calculated. The option with the highest NPV is compared with the total NPV of the baseline solutions for the area covered by the district heating. Where the NPV of the district heating solution is better than the baseline that solution is selected. If the baseline is more cost effective, district heating is not selected. Consequently district heating may be selected by the model to cover all, part, or none of the MSOA.

   NB: As described in section 2.2.4, the modelling has assumed that industrial facilities will not be served by district heating due to process requirements being generally for higher grades of heat.
2. Then, for individual properties in areas not covered by a selected DH option, the NPV of all technically suitable individual CHP options is calculated and the option with the highest NPV selected.
3. For individual properties not assigned to a DH or individual CHP option in the above steps, the NPVs for alternative individual high-efficiency solutions (heat pumps, biomass boilers and solar thermal) were calculated and the option, including the baseline, with the best NPV is selected.

2.2.6 Scenarios

The results of the modelling undertaken for the NCA are by the nature of the analysis uncertain. Uncertainty arises as a consequence of inter alia the following:

- **Data availability and quality.** Where data has not been available or of sufficient quality, then simplifying assumptions have to be made and/or the approach modified.
- **Striving for accuracy results in greater complexity.** There are practical limits to the level of detail that a model can deal with even if there is sufficient information available
- **Assumptions are inevitable.** Parameters such as capital and operating costs have to be simplified to what is considered 'typical' from the evidence available.

To deal with the inherent uncertainty, the cost-benefit analysis has been undertaken under a number of scenarios around a reference '*Full financing costs*' scenario that represents a no government policy situation, in particular regarding the de-risking investments in infrastructure.

Various scenarios have been run using the high and low IAG values for energy and carbon prices, ± 20% for capital and operational costs, and higher and lower costs of finance. All of the scenarios assume that all technologies are replaced in one go in 2015.

Two 'extreme' scenarios have also been investigated:

- A '*Zero financing costs*' scenario where the cost of finance is taken as zero; a totally de-risked scenario.
- An '*Extreme carbon price*' scenario where a carbon price of £500/tCO_2 has been taken.

These together with the reference *Full financing costs*' scenario are summarised in Table 2.4

Table 2.4: Cost-benefit analysis scenario summary

Scenario / Variable	Full financing costs	Zero financing costs	Extreme carbon price
Cost of finance	15% for industry, 10% for non-industrial sectors[29]	0% all sectors	15% for industry, 10% for non-industrial sectors
Energy prices	IAG 2014 long-run variable cost (LRVC) of energy supply, central values	IAG 2014 long-run variable cost (LRVC) of energy supply, central values	IAG 2014 long-run variable cost (LRVC) of energy supply, central values
Carbon prices	IAG 2014 carbon prices traded and non-traded, central values	IAG 2014 carbon prices traded and non-traded, central values	£500 per tonne of CO_2
Capex and opex	UK best evidence values for each technology	UK best evidence values for each technology	UK best evidence values for each technology

2.3 Study limitations

A national level analysis of this nature is subject to not insignificant uncertainty since mainly high-level data are employed to analyse the situation for the entire country. A strength of the modelling is that it has taken, as far as possible, a building by building approach (there are approximately 29 million buildings in the UK), but inevitably there are limits to the quality of information at this level, such as building type, size, heat demand profile, heating fuel, etc. Striving for accuracy results in greater complexity; even with perfect information, there are practical limits to the level of detail with which a model can reasonably cope.

Where data has not been available or is of insufficient quality, then simplifying assumptions have been made. Parameters such as capital and operating costs have to be simplified to what is considered 'typical' from the evidence available. The modelling is undertaken in a broad-brush manner and cannot fully capture local conditions and distributional variations in costs and benefits; the results should therefore be taken as indicative. Furthermore the methodology used has been driven by the requirements of the Directive; consequently comparison of the findings in this document with other studies, including government and academic studies, may be misleading and should be treated with caution.

To deal with the inevitable uncertainties, the cost-benefit analysis has been undertaken under a range of scenarios (sensitivities) to determine the impact of assumptions regarding capital and maintenance costs, energy prices, finance costs and carbon prices.

A further limitation is that district heating systems have mainly been modelled with only a single heat raising technology rather than a mixture of heat sources, which is likely to be the case with many actual schemes. Schemes have been modelled at two different scales, but in reality there will be a significant number of possible sizes, configurations and technologies. The results therefore cannot be used to judge the viability of specific prospective schemes, which could only be determined by conducting a detailed design study to optimise the coverage and layout of heat distribution network, to size the central plant to meet the daily, weekly and seasonal patterns of heat demand within a particular area, and to take advantage of low cost and low carbon waste heat sources. The scope for phasing the development of district heating networks and use of modular central plant designs may also have an effect on the cost-effectiveness of prospective schemes that could only be explored during a detailed investment appraisal.

Similarly the representation of individual solutions is constrained to a relatively small subset of the potential options available to heating system design engineers, and may not capture the complete potential for individual technologies identified by market studies. This is particularly the case for heating options related to flats and industrial properties were assumptions on the limited scope for deploying biomass boilers, heat pumps and district heating were made to avoid modelling large numbers of unrealistic solutions.

[29] The cost of finance captures investment risk; the values used for the full financing costs scenario were taken on the advice of DECC senior economists

3 Results

The results of the comprehensive assessment for the UK are presented in the following sections reflecting the sequence of the methodology steps described in section 2. Heat policy in the UK is a devolved matter in Scotland and Northern Ireland, but not currently in Wales. In the following sections the results are presented for the UK and specifically for Scotland. Results tables and heat maps for Wales, Northern Ireland and the nine English regions are provided in Appendix 1.

The results are all presented in terms of annual heat in terawatt hours (TWh) rounded to the nearest terawatt hour (TWh).

3.1 Current and projected heating and cooling consumptions

3.1.1 Heating consumption

The analysis has enabled the heat consumption for each of the 29 million demand points in the UK to be estimated. Table 3.1 shows the aggregated 2012 heat consumption for each devolved administration and English region, split by sector[30]: industry (including agriculture); commercial services; public services; and residential. This is the 'useful' heat output from heat raising plant, i.e. it excludes heat rejected in cooling towers but includes losses in existing DH networks. Existing non-industrial DH schemes have been assigned to the commercial sector.

Table 3.1: UK 2012 heat consumption for devolved administrations and English regions by sector, TWh of heat pa

NUTS112 Code	Devolved administration / English region	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial services TWh pa	Public sector TWh pa	Residential TWh pa
UKC	North East	**25**	11	1	1	13
UKD	North West	**63**	21	4	4	33
UKE	Yorkshire & the Humber	**56**	25	2	3	26
UKF	East Midlands	**29**	5	1	1	22
UKG	West Midlands	**33**	3	2	2	26
UKH	East of England	**39**	7	1	2	28
UKI	London	**42**	2	3	3	34
UKJ	South East	**60**	13	3	2	41
UKK	South West	**29**	2	1	2	24
UKL	Wales	**30**	10	1	2	17
UKM	Scotland	**65**	22	5	3	35
UKN	Northern Ireland	**15**	2	0	0	12
	UK totals	**484**	**123**	**23**	**25**	**312**

Table 3.2 shows the equivalent figures as projected to 2025. Figure 3.1 shows that a general downward trend in heating consumption is anticipated over the next 10 years. The UEP projections take account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made, including measures such as building regulations.

[30] Sectors used in the analysis are those defined in DECC's Updated energy and emissions projections: 2014 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

Table 3.2: UK 2025 projected heat consumption for devolved administrations and English regions by sector, TWh of heat pa

NUTS112 Code	Devolved administration / English region	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial services TWh pa	Public sector TWh pa	Residential TWh pa
UKC	North East	**22**	10	1	1	11
UKD	North West	**55**	20	3	3	29
UKE	Yorkshire & the Humber	**50**	24	1	2	23
UKF	East Midlands	**25**	4	1	1	19
UKG	West Midlands	**29**	3	1	2	23
UKH	East of England	**34**	7	1	1	25
UKI	London	**37**	2	2	2	30
UKJ	South East	**53**	12	3	2	36
UKK	South West	**26**	2	1	1	21
UKL	Wales	**27**	10	1	1	15
UKM	Scotland	**57**	21	3	2	31
UKN	Northern Ireland	**13**	2	0	0	11
	UK totals	**429**	**117**	**18**	**20**	**275**

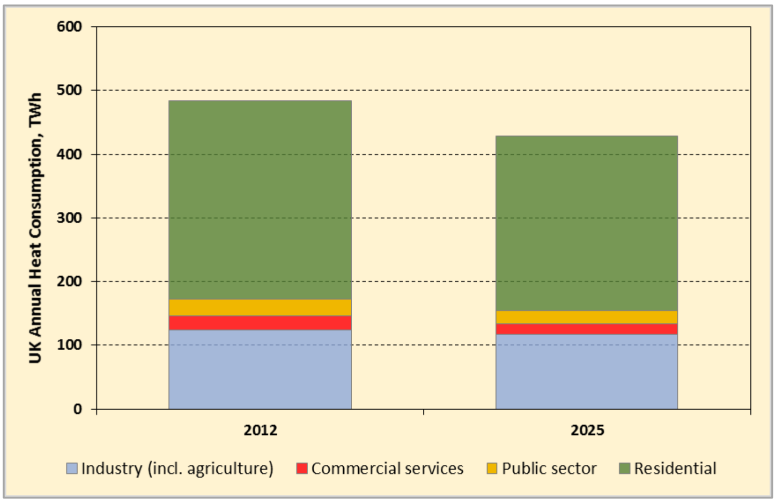


Figure 3.1: UK projected annual heat consumption to 2025

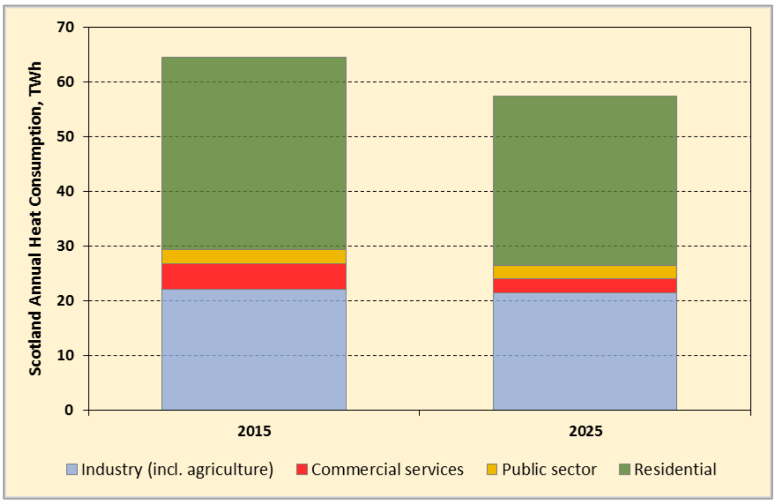


Figure 3.2: Scotland projected annual heat consumption to 2025

3.1.2 Cooling consumption

Tables 3.3 and 3.4 show the current and projected space cooling consumption for each for devolved administration and English region, split by sector. Given the paucity of available data on actual energy consumption for cooling, these figures are estimates based on consumption indicators, building types and floor areas; consequently they should be considered as indicative. It has been assumed that cooling in the residential sector is negligible.

Table 3.3: UK 2012 cooling consumption for devolved administrations and English regions by sector, TWh of cooling pa

NUTS112 Code	Devolved administration / English region	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial services TWh pa	Public sector TWh pa
UKC	North East	**1**	0	0	0
UKD	North West	**3**	1	1	0
UKE	Yorkshire and The Humber	**3**	1	1	1
UKF	East Midlands	**3**	2	1	0
UKG	West Midlands	**3**	2	1	0
UKH	East of England	**6**	4	1	0
UKI	London	**18**	3	13	1
UKJ	South East	**15**	10	3	1
UKK	South West	**5**	3	1	0
UKL	Wales	**1**	1	0	0
UKM	Scotland	**2**	1	1	0
UKN	Northern Ireland	**1**	0	0	0
	Total	**59**	**30**	**24**	**5**

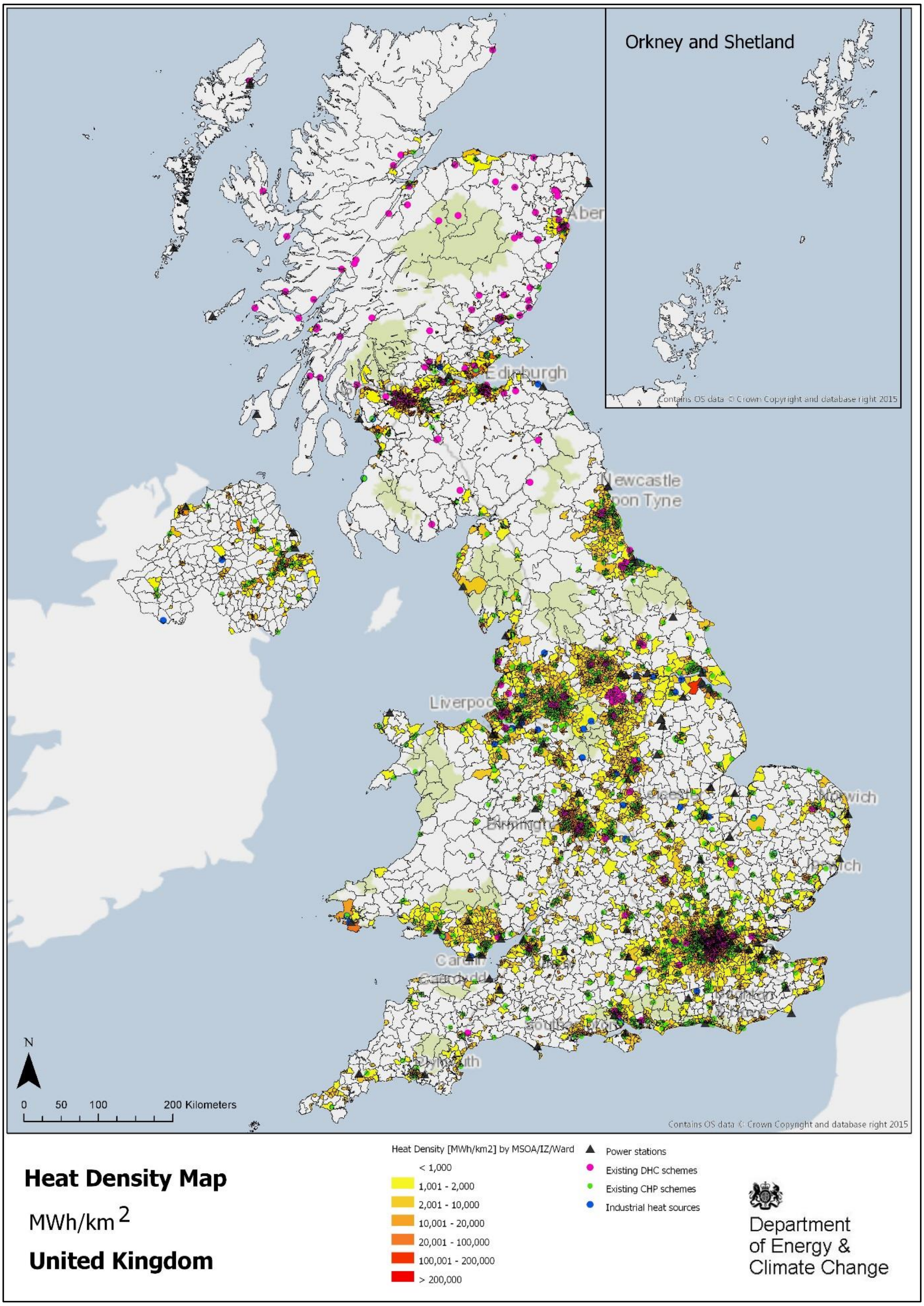
Table 3.4: UK 2025 cooling consumption for devolved administrations and English regions by sector, TWh of cooling pa

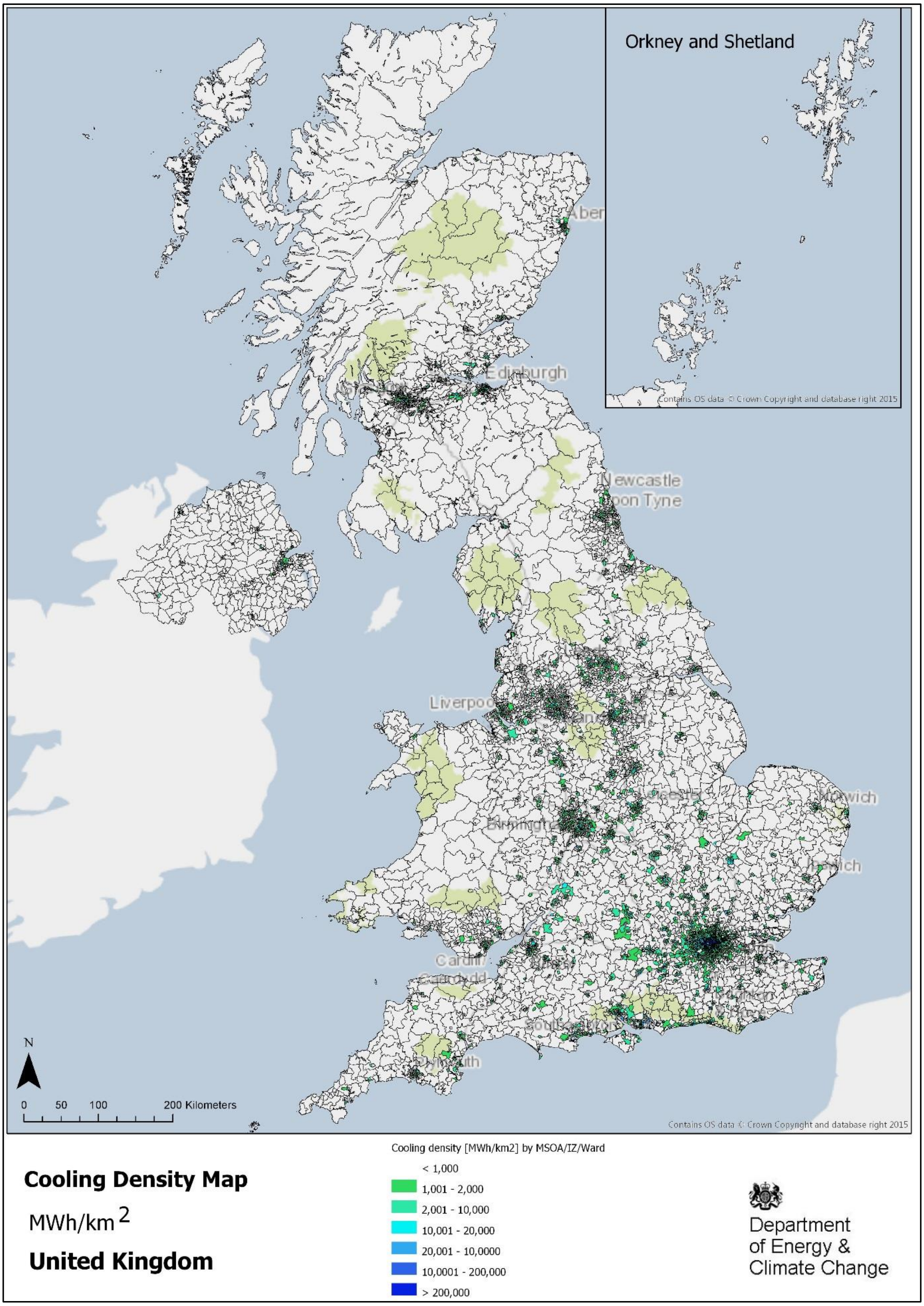
NUTS112 Code	Devolved administration / English region	Total TWh pa	Industry (incl. agriculture TWh pa	Commercial services TWh pa	Public sector TWh pa
UKC	North East	**0**	0	0	0
UKD	North West	**2**	1	1	0
UKE	Yorkshire and The Humber	**3**	1	1	0
UKF	East Midlands	**2**	1	1	0
UKG	West Midlands	**3**	2	1	0
UKH	East of England	**5**	4	1	0
UKI	London	**15**	3	11	1
UKJ	South East	**13**	10	3	1
UKK	South West	**4**	3	1	0
UKL	Wales	**1**	1	0	0
UKM	Scotland	**2**	1	0	0
UKN	Northern Ireland	**1**	0	0	0
	Total	**52**	**28**	**20**	**4**

3.2 Heat and cooling maps

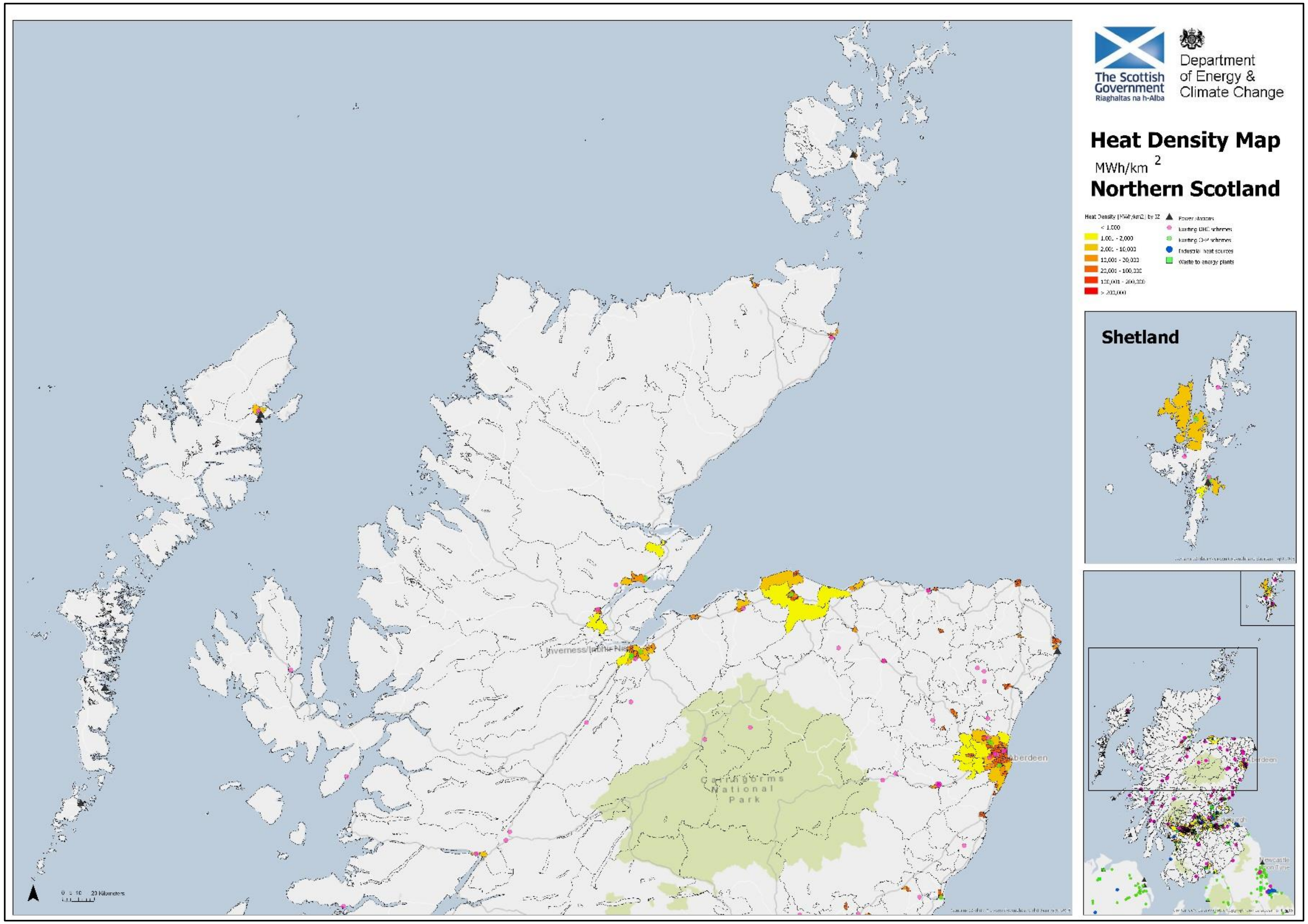
Heat and cooling maps have been produced for the entire UK and as well as showing heat and cooling density include mapping layers for existing power stations, CHP installations, district heating schemes and potential sources of industrial waste heat. Below are sample maps for the UK and for Scotland. Maps for Wales, Northern Ireland and English regions are provided in Appendix 1.

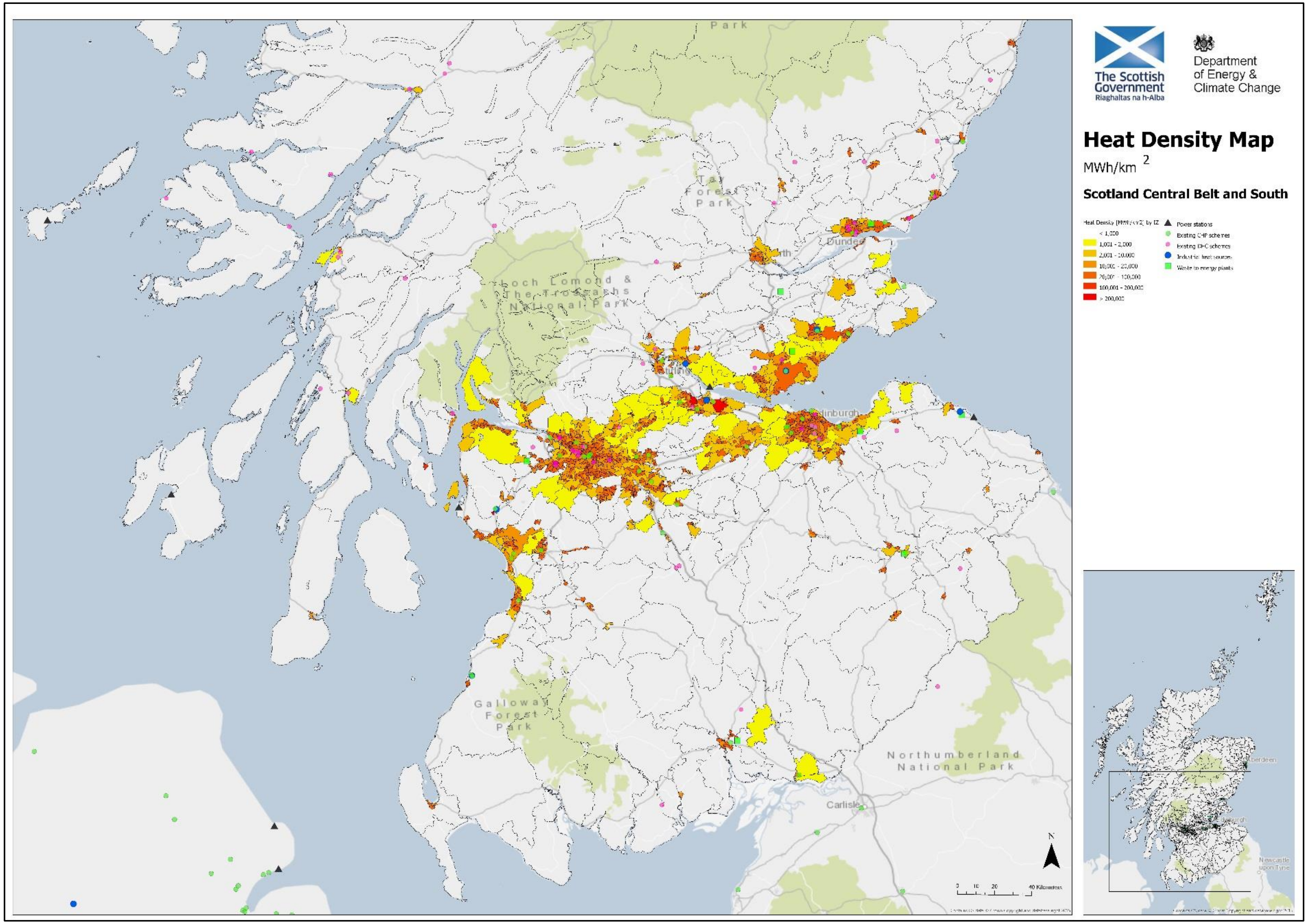
3.2.1 United Kingdom maps

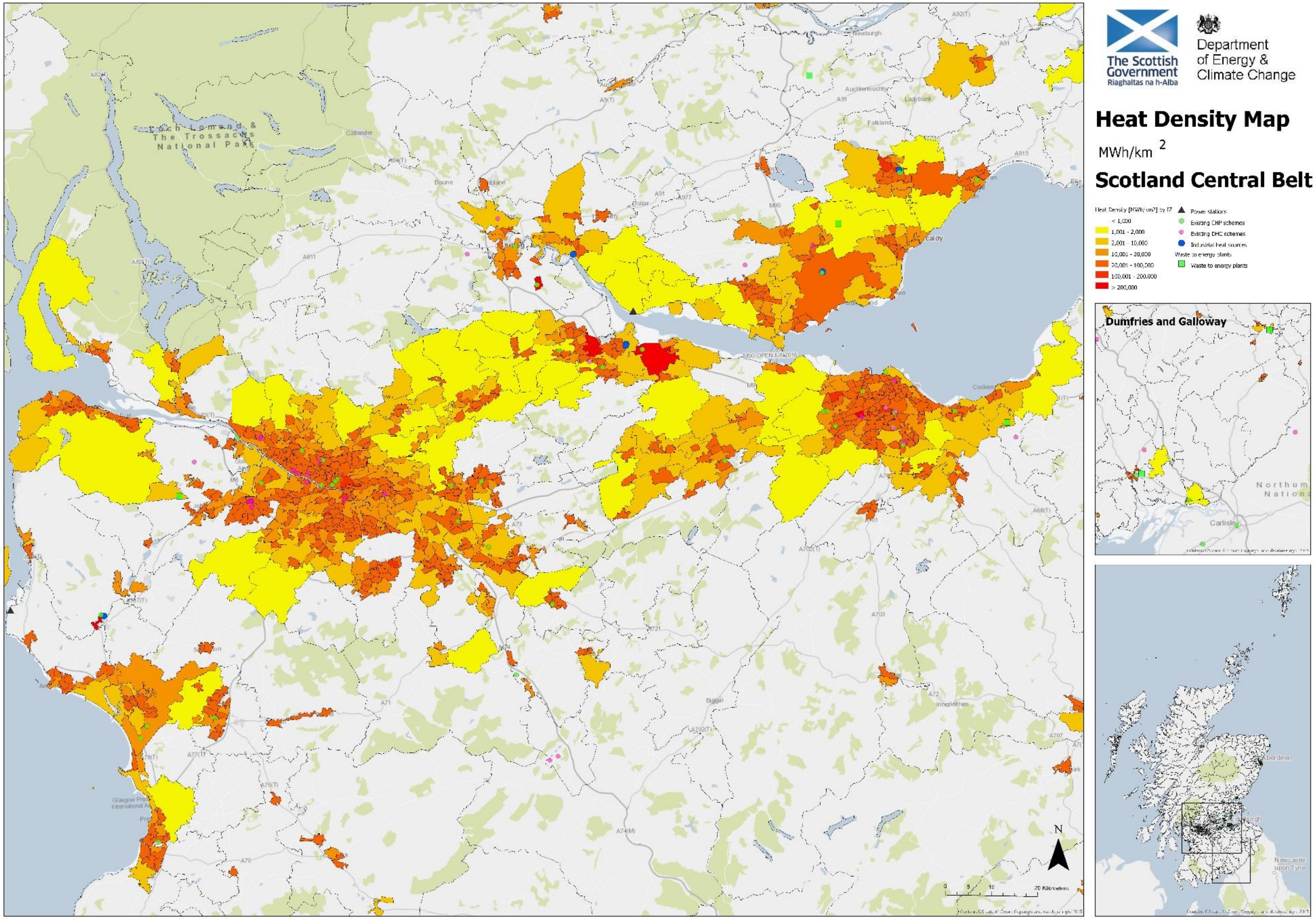


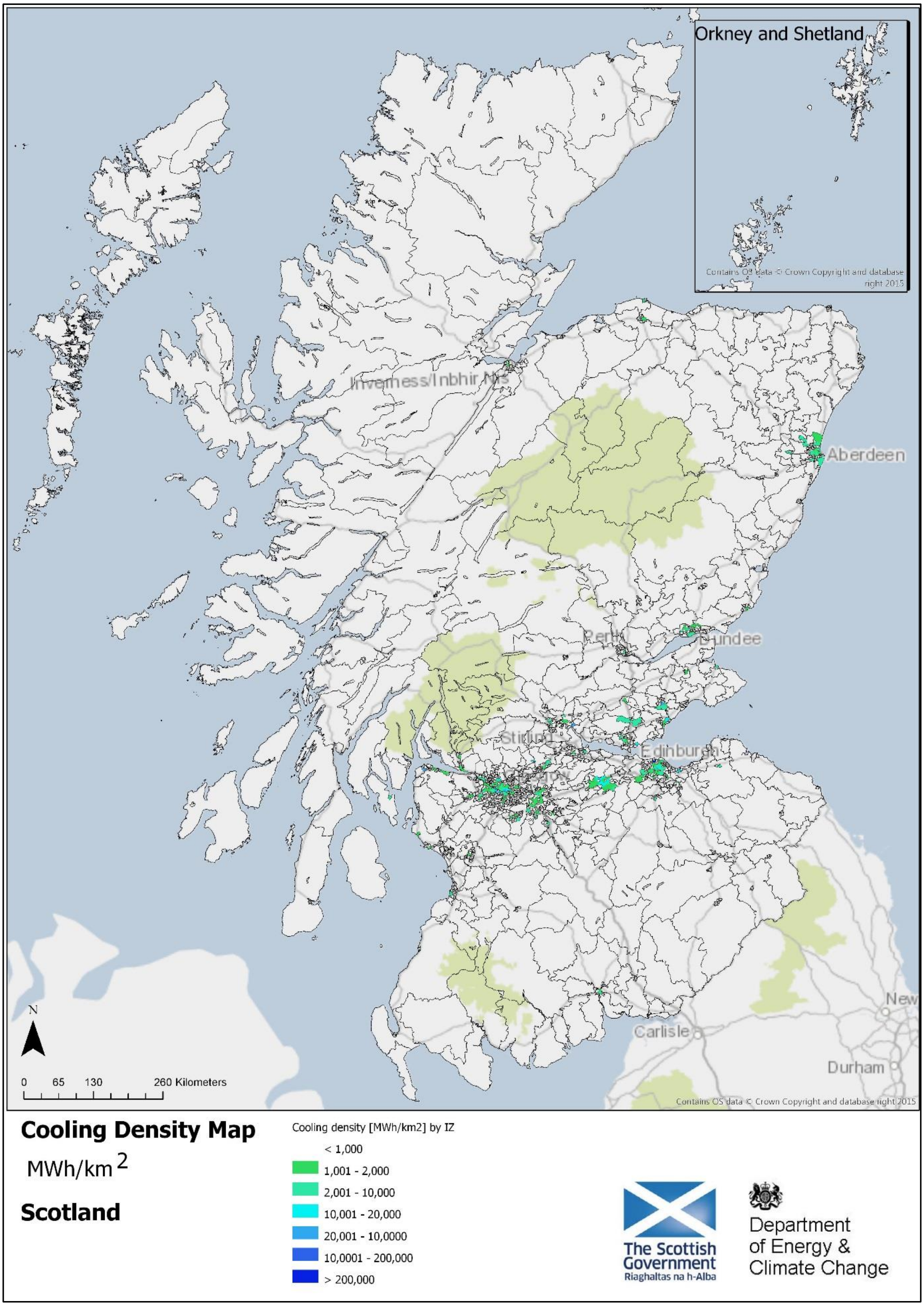

Orkney and Shetland
Edinburgh
Newcastle upon Tyne
Contains OS data © Crown Copyright and database right 2015
N
0 50 100 200 Kilometers
Contains OS data © Crown Copyright and database right 2015
Cooling Density Map
MWh/km 2
United Kingdom
Cooling density [MWh/km2] by MSOA/IZ/Ward
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 10,0000
10,0001 - 200,000
> 200,000
Department of Energy & Climate Change

3.2.1 Scotland maps




Heat Density Map
MWh/km 2
Scotland Central Belt and South
Power stations
Existing CHP schemes
Industrial heat sources
Waste to energy plants
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
100,001 - 200,000
> 200,000
Loch Lomond & The Trossachs National Park
Galloway Forest Park
Northumberland National Park
Dundee
Carlisle
N


The Scottish Government
Riaghaltas na h-Alba
Department of Energy & Climate Change
Heat Density Map
MWh/km 2
Scotland Central Belt
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing CHP schemes
Existing DHC schemes
Industrial heat sources
Waste to energy plants
Waste to energy plants
Dumfries and Galloway
Loch Lomond & The Trossachs National Park
Carlisle
N
0 5 10 20 Kilometers


Orkney and Shetland
Contains OS data © Crown Copyright and database right 2015
Inverness/Inbhir Nis
Aberdeen
Perth
Dundee
Stirling
Edinburgh
Carlisle
Durham
N
0 65 130 260 Kilometers
Contains OS data © Crown Copyright and database right 2015
Cooling Density Map
MWh/km 2
Scotland
Cooling density [MWh/km2] by IZ
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 10,0000
10,0001 - 200,000
> 200,000
The Scottish Government
Riaghaltas na h-Alba
Department of Energy & Climate Change

3.3 Technical potentials

The technical potentials of the high-efficiency solutions have been calculated independently of each other with no reference to economic factors. The technical potential of a particular solution therefore represents a maximum technically possible deployment of the technology irrespective of costs.

The baseline and the technical potentials are presented below for the whole of the UK and for Scotland. Appendix 1 provides equivalent tables of the baseline and technical potentials for Wales, Northern Ireland and the nine English regions.

Baseline

The composition of the baseline is shown for the UK and Scotland respectively in Tables 3.5 and 3.7. This is the assumed business as usual scenario described in section 2.2.4. The total baseline heat outputs don't exactly match the 2012 heat consumption figures in Table 3.1 due to a few areas being excluded from the modelling where data quality was very poor, and also to the filtering out of very small heat loads that are not amenable to high-efficiency solutions.

Technical potentials

The technical potentials for high-efficiency solutions are shown for the UK and Scotland respectively in Tables 3.6 and 3.8. Existing CHP that is in the baseline is included in the technical potentials under the relevant high-efficiency individual and district heating solutions.

The technical potentials for the individual solutions are not additive as each is derived independently of the technical potential for other solutions. In the assessment of socially cost-effective potentials the solutions with technical potential, including those in the baseline, compete for the same heat loads on the basis of most favourable NPV.

The assessed technical potentials arise partly as a result of the limitations outlined in section 2.2.4 that restrict the applicability of technologies under particular circumstances. In addition, the following also affect the technical potential results:

- District heating in the modelling was limited to areas above a certain level of building density defined as a *plot ratio* of at least 0.3. The plot ratio of a particular defined area is the total building area (including the areas of multiple storeys) divided by the land area. This threshold is specified in the Directive.
- The technical potential for the use of waste heat sources (power stations, waste incinerators and industrial waste heat) depends on the availability of heat loads in proximity to the sources. A 15 km radius was assumed as a practical limit for transporting the heat. Only directly usable grades of heat were considered; the possible use of heat pumps to increase the grade of the waste heat was not included in the analysis. No account has been taken of the possible use of waste heat by other industrial sites since specific site by site information would be needed, including on the grades of heat required and the quantities thereof. An Element Energy led study for DECC published in 2014[31] investigated the potential for recovering and using surplus heat from industry, identifying a technical potential of 7 TWh pa for on-site use and 3 TWh pa for use by other nearby industrial sites.
- For water source heat pumps serving district heating the analysis has been limited to England due to data availability and the assessment was undertaken on the basis of MSOAs containing or adjacent to bodies of water.

[31] https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

3.3.1 United Kingdom

The total heat requirement in the UK for which heat supply solutions have been modelled is 465 TWh pa.

Table 3.5: UK baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
Baseline, total	**465**	**123**	**22**	**25**	**294**
Heat only gas/oil boilers	410	94	19	24	272
Electric heating	35	11	2	0	22
CHP and backup boilers	20	18	1	1	

Table 3.6: UK technical potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh pa	Industry (incl. agriculture TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
Individual	Gas CHP + gas boilers	401	112	20	25	244
	Biomass CHP + gas boilers	46	38	2	6	
	Biomass boilers	167	39	7	9	112
	Air to water heat pumps	334		19	23	291
	Ground source heat pumps	267		19	23	225
	Solar thermal + gas boilers	322		19	23	280
	Solar thermal + biomass boilers	160		7	9	144
District heating	Gas CHP + gas boilers	276		276		
	Biomass CHP + gas boilers	276		276		
	Biomass boiler	276		276		
	Ground source heat pumps	276		276		
	Water source heat pumps	114		114		
	Power station heat	46		46		
	Waste incinerator heat	3		3		
	Industrial waste heat	3		3		

3.3.2 Scotland

The total heat requirement in Scotland for which heat supply solutions have been modelled is 60 TWh pa.

Table 3.7: Scotland baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
Baseline, total	**60**	**22**	**5**	**3**	**31**
Heat only gas/oil boilers	52	19	3	2	27
Electric heating	5	0	1	0	4
Gas CHP and backup boilers	3	3	0	0	

Table 3.8: Scotland technical potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
Individual	Gas CHP + gas boilers	54	22	3	3	26
	Biomass CHP + gas boilers	3	2	1	1	
	Biomass boilers	13	2	1	1	9
	Air to water heat pumps	36		3	2	31
	Ground source heat pumps	27		3	2	22
	Solar thermal + gas boilers	27		3	2	21
	Solar thermal + biomass boilers	11		1	1	9
District heating	Gas CHP + gas boilers	34		34		
	Biomass CHP + gas boilers	34		34		
	Biomass boiler	34		34		
	GSHP	34		34		
	Power station heat	4		4		
	Waste incinerator heat	0		0		
	Industrial waste heat	0		0		

3.4 Socially cost-effective potentials

For each geographic area (MSOAs in England and Wales, IZs in Scotland, and Wards in NI) the high-efficiency solutions with technical potential in that area, including conventional baseline solutions, are compared to determine the socially cost-effective potential for each according to the process described in section 2.2.5. The resulting mix of solutions has been modelled to supply the heat provided by the baseline scenario. However, the actual heat delivered by the mix of solutions changes with the amount of district heating in the mix since with greater district heating deployment the greater are the total network losses that need to be served. Consequently the total heat output from the socially cost-effective solutions differs slightly from the total baseline and varies from scenario to scenario.

The socially cost-effective heat output potential results for the full financing costs scenario are shown respectively for the UK and Scotland in Tables 3.9 and 3.12. In these tables:

- The total heat output potential for high-efficiency solutions is shown in the top row of the table and includes existing Good Quality[32] (i.e. high-efficiency) CHP.
- The '*Conventional, total*' row shows the totals for where conventional boilers or electric heating have the best NPV.
- The totals for all solutions are shown in the bottom row, approximating to the 2012 heat consumption.

Despite the low social discount rate of 3.5%, the socially cost-effective potential for high efficiency heating solutions is only about 28.2% of total UK heat consumption under the full finance costs scenario, with district heating contributing 3.2%. For Scotland, the equivalent figures are 46.7% and 6.7% of total heat consumption in Scotland.

These apparent low economic potentials for high-efficiency solutions is at least in part reflective of the extensive gas network already being in place in the UK and the relatively low capital and fuel cost of boiler heating. District heating systems in particular require significant expenditure on network infrastructure and as a general rule tend to be uneconomic without a supply of low cost heat.

Within the individual high-efficiency potential, gas CHP dominates, with other individual solutions contributing only relatively small amounts of cost-effective potential. A similar picture is found within the district heating potential.

As described in section 2.2.6, a number of alternative scenarios (or sensitivities on the central scenario) have been run. The low and high (± 20%) capex and opex scenarios and the low and high IAG energy and carbon price scenarios show a very similar picture as the full finance costs reference scenario with only slight movements in the potentials for high-efficiency solutions.

The cost of finance can add significantly to project costs. The results of the zero financing costs scenario, which represents a wholly de-risked situation are shown in Table 3.10 for the UK and Table 3.13 for Scotland. The significantly greater potential for district heating under the zero cost of finance is a direct reflection of the high infrastructure costs of district heating networks where there is a step increase in capital costs compared with individual solutions, even with the benefits of economies of scale.

Under the extreme carbon price scenario £500 per tCO_2 for each year replaces the IAG central carbon prices used in the other scenarios, which range from £62 to £72 per tCO_2 between 2015 and 2025 in the non-traded sector and are lower for the traded sector. The results of this scenario are presented in Table 3.11 for the UK and Table 3.14 for Scotland; high-efficiency solutions represent around 75% of annual heat supply for both the UK and Scotland.

At the higher carbon prices there is, as one would anticipate, a shift away from natural gas to non-gas CHP high-efficiency solutions, particularly to biomass and for district heating to sources of recoverable heat and water source heat pumps. The economic potential for gas-fired CHP for district heating falls off significantly in favour of biomass and recoverable heat. For individual solutions the shift away from gas-fired CHP is less severe but still significant, particularly towards biomass CHP, biomass boilers and air-source heat pumps.

[32] Good Quality CHP is the UK equivalent of high-efficiency CHP, defined under the government's CHPQA programme, https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme

A side-by-side comparison of the three scenarios is shown respectively for the UK and Scotland in Figures 3.3 and 3.4. These results illustrate the potential effectiveness of two levers that can be employed to pull forward high-efficiency heating, one involving de-risking capital investment in high efficiency heating solutions and the other introducing mechanisms for cost equalisation dependent on the carbon content of the heat.

3.4.1 United Kingdom

Table 3.9: UK cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**131**	**101**	**30**		
Individual	*116*	*101*	*4*	*9*	*2*
District heating	*15*		*15*		
Conventional, total	**334**	**22**	**13**	**11**	**289**
Total heat output	**465**	**123**	**342**		

Table 3.10: UK cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**314**	**109**	**204**		
Individual	*128*	*109*	*2*	*3*	*13*
District heating	*186*		*186*		
Conventional, total	**168**	**14**	**5**	**3**	**145**
Total heat output	**481**	**123**	**358**		

Table 3.11: UK cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**358**	**103**	**255**		
Individual	*200*	*103*	*4*	*6*	*87*
District heating	*158*		*158*		
Conventional, total	**120**	**21**	**4**	**1**	**94**
Total heat output	**477**	**123**	**354**		

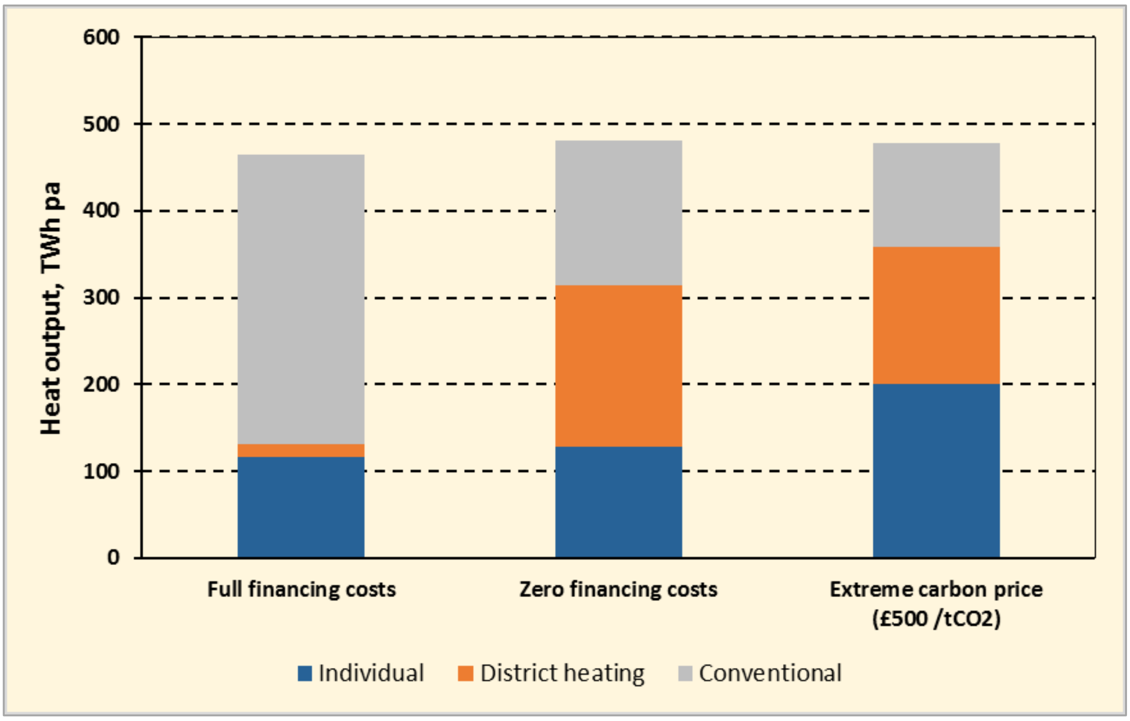


Figure 3.3: UK comparison of scenarios - split of cost-effective heat supply solutions

3.4.2 Scotland

Table 3.12: Scotland cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**28**	**21**		**6**	
Individual	*23*	*21*	*1*	*1*	*0*
District heating	*4*			*4*	
Conventional, total	**33**	**1**	**2**	**1**	**28**
Total heat output	**60**	**22**		**38**	

Table 3.13: Scotland cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**50**	**21**		**28**	
Individual	*23*	*21*	*0*	*0*	*1*
District heating	*27*			*27*	
Conventional, total	**10**	**0**	**1**	**0**	**8**
Total heat output	**60**	**22**		**38**	

Table 3.14: Scotland cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**45**	**20**	**24**		
Individual	*24*	*20*	*1*	*1*	*2*
District heating	*21*		*21*		
Conventional, total	**14**	**1**	**1**	**0**	**12**
Total heat output	**59**	**22**	**37**		

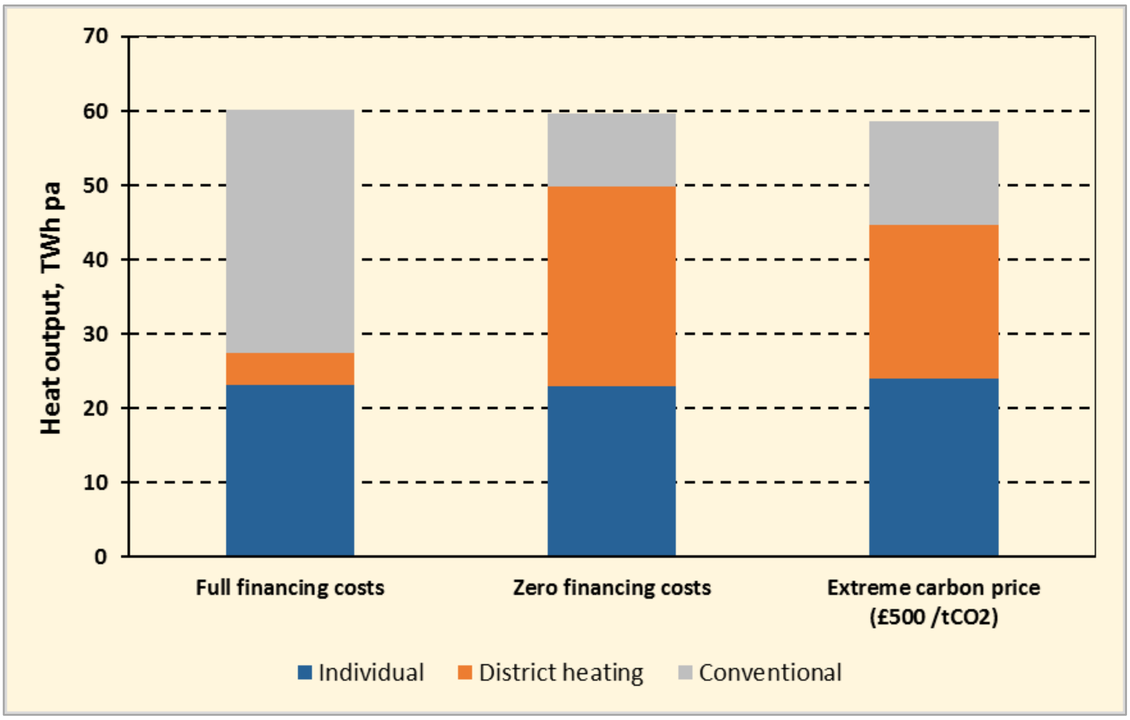


Figure 3.4: Scotland split of cost-effective heat supply solutions under enhanced carbon price scenarios

4 Strategies, policies and measures

This section describes existing relevant government policies and measures that are supporting the greater deployment of high-efficiency CHP and efficient district heating and cooling systems. As a result of the devolution of powers within the UK to the Devolved Administrations in Scotland, Wales and Northern Ireland, the geographical coverage is noted for each policy.

4.1 Policies supporting high-efficiency CHP

4.1.1 CHP Quality Assurance programme (UK)

The UK Government has introduced a number of fiscal and financial support mechanisms designed to improve the economics of developing and operating CHP plants certified, either fully or partly, as “Good Quality” by the CHP Quality Assurance programme (CHPQA). CHPQA is consistent with the EU definition of high-efficiency CHP/cogeneration.

CHPQA certification may be used to support a claim for a range of benefits including:

- Exemption from the main rates of climate change levy (CCL) and fuel-oil duty
- Exemption from the carbon price support (CPS) tax
- Enhanced Capital Allowances
- Exemption from Business Rates of Power Generating Plant and Machinery

Renewable CHP technologies may also qualify for support from the:

- Renewables Obligation
- Contracts for Difference
- Renewables Heat Incentive
- Feed-in Tariff

Any support so received is in addition to the commercial value of any heat and power generated.

There are some variations in treatment across the countries of the UK, which are noted in the following sections.

4.1.2 Climate Change Levy exemption (UK)

The Climate Change Levy (CCL) was introduced by the UK Government in 2001 and is an energy efficiency tax applied throughout the UK on most non-domestic supplies of energy. CHP schemes that are certified as Good Quality are exempt from the main rates of CCL on the fuel they use and electricity they supply to themselves and directly to other consumers (i.e. that which is not supplied via a utility).

4.1.3 Carbon Price Support exemption (Great Britain)

The Carbon Price Support (CPS) was introduced on 1 April 2013 as a tax on fossil fuels used to generate electricity where the generating station has a capacity of 2 MWe or more. This was introduced by the UK government in response to the low price of carbon in the European Union Emissions Trading System (EU-ETS). The CPS does not apply in Northern Ireland due to the common electricity market with the Republic of Ireland.

With effect from the 1 April 2015, the Government introduced an exemption from the CPS rates for fuels that are used by a CHP plant to generate Good Quality electricity for use ‘on site’.

4.1.4 Hydrocarbon Oil Duty Relief (UK)

CHP schemes that are certified as “Good Quality CHP” under CHPQA are able to claim a refund of Hydrocarbon Oils duty on oil used to generate electricity on an annual basis.

4.1.5 Enhanced Capital Allowances (UK)

The Enhanced Capital Allowances (ECA) scheme allows businesses to write-off 100% of their investment in those energy saving technologies, such as Good Quality CHP, that are listed in the Energy Technology Criteria List (ETL), against the taxable profits of the accounting period during which they make the investment.

4.1.6 Business Rating Exemption (Great Britain)

A business rating exemption applies to specified plant and machinery contained within Good Quality CHP schemes that are fully or partially certified as "Good Quality CHP" under CHPQA and have obtained a Secretary of State (CHP) Exemption Certificate. The exemption extends to accessories associated with the power generating plant and machinery but not to heat recovery plant and machinery[33].

In Northern Ireland the business rating exemption is restricted to micro-CHP on or attached to an existing building. Micro-CHP means a maximum electrical capacity of 50kWe and/or a maximum heat capacity of 45kW.

4.1.7 Renewables Obligation (UK)

The Renewables Obligation (RO) was introduced to support electricity generation from renewable sources. The RO came into effect in 2002 in England and Wales, and Scotland, followed by Northern Ireland in 2005. It places an obligation on UK electricity suppliers to source a growing percentage of electricity from eligible renewable generation capacity. Suppliers are required to produce evidence of their compliance with this obligation via certificates, referred to as Renewables Obligation Certificates (ROCs). Each ROC nominally represents 1MWh of electricity generated from eligible renewable sources towards their obligation. There are some differences between the Scottish Renewables Obligation (SRO), the Northern Ireland Renewables Obligation (NIRO) and the Renewable Obligation in England and Wales[34]; each comes under separate legislation.

The detailed rules for support levels under the RO are set out in the Renewables Obligation Orders. The level of support for renewable electricity generated by good quality CHP is:

- 1.9 ROCs/MWh (2015/16) for new schemes fuelled wholly by 'regular'[35] biomass (includes 0.4 ROC uplift relative to biomass power-only plant, but only where support under the RHI is not available).
- 1.0 ROCs/MWh for energy from waste schemes.

To qualify for these ROC allowances, an additional CHPQA Certificate (GN44 'ROC Eligible' Certificate) is required based on a separate assessment to that used to access other benefits available to GQCHP.

Where a CHPQA GN44 'ROC eligible' certificate has been issued (providing eligibility for the CHP 'ROC Uplift'), participants are ineligible to claim support on the heat output under the Renewable Heat Incentive (RHI) – see section 4.1.9.

4.1.8 Contracts for Difference (Great Britain)

The Contracts for Difference (CfD) regulations came into force in Great Britain on the 1st August 2014; CfDs will replace the RO for new projects targeting commissioning from 1st April 2017 (RO grace periods allow certain slippage to commissioning beyond 31st March 2017). A final decision has still to be taken by Northern Ireland as to its inclusion in the CfD mechanism. CfDs are awarded competitively to the best value projects via an allocation round process.

A generator party to a CfD is paid the difference between the 'strike price' (a price for electricity reflecting the cost of investing in a particular low carbon technology) and the 'reference price' (a measure of the average market price for electricity). In the event that the reference price exceeds the strike price the generator pays the difference to the Low Carbon Contracts Company, a Government-owned but arms-length company.

Biomass CHP and energy from waste CHP are eligible to compete for support in CfD allocation rounds, but biomass and energy from waste power-only projects are not eligible for CfD support. Support under the CfD will be paid only on the proportion of metered electrical output assessed by CHPQA to be "Good Quality". Energy from waste CHP generators are ineligible to apply for CfDs if they have also applied for accreditation under the RHI.

[33] Further information at: https://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_43.pdf

[34] Further information at: https://www.ofgem.gov.uk/environmental-programmes/renewables-obligation-ro

[35] 'Regular' biomass is defined as biomass other than (a) sewage gas, (b) landfill gas, (c) energy crops, (d) fuel produced by means of anaerobic digestion, (e) advanced fuel.

4.1.9 Renewable Heat Incentive (separate schemes in Great Britain and Northern Ireland)

Great Britain

The Renewable Heat Incentive (RHI), launched in November 2011, is designed to provide support to renewable heat technologies in order to increase deployment and aid market development with the ultimate aim of reducing costs of installation. The RHI provides support where heat is used in a building for 'eligible purposes': heating a space, heating water or for carrying out a process where the heat is used. Heat used for electricity generation does not qualify for the RHI.

Solid biomass CHP installations (excluding solid biomass contained in waste) are eligible for the new solid biomass CHP tariff on their eligible heat output if:

- the installation/relevant combustion unit(s)/conversion from power only generation was commissioned on or after 4 December 2013.
- the relevant combustion unit(s) are new at the time of installation
- the installation is certified under CHPQA. Applicants will have to provide evidence of current CHPQA certification as part of the accreditation process in order to be awarded this tariff
- the relevant combustion unit(s) are designed and installed to burn solid biomass only (not including solid biomass contained in waste)
- the relevant combustion unit(s) comply with the air quality requirements

The rate at which the RHI is paid to other renewable CHP plant eligible for support (solid biomass in waste, geothermal and biogas), is dependent on the thermal output capacity and fuel type.

Northern Ireland

Northern Ireland has its own Renewable Heat Incentive, both domestic and non-domestic. Northern Ireland makes its own regulations for the schemes and sets its own tariffs and technologies. Changes have recently been introduced to the Northern Ireland RHI and include two new tariffs for CHP to coincide with the changes in the NIRO. New installations using solid biomass will receive a tariff of 3.5 pence per kWh and installations converting from fossil fuels will receive a tariff of 1.7 pence per kWh.

4.1.10 Feed-in Tariff (Great Britain)

The Feed-in Tariff (FiT) was introduced by the UK Government in order to support renewable electricity generating technologies of up to 5 MWe in capacity. Currently, the only renewable fuel CHP technology supported by the FiT scheme is anaerobic digestion (excluding sewage gas). Solid biomass, sewage gas and landfill gas CHP are specifically excluded from the FiT scheme on the grounds that there is adequate support available through the RO scheme. The FiT scheme also includes a pilot which provides support to domestic scale micro-CHP installations. Micro-CHP units are normally fuelled by natural gas and must have an installed capacity of 2 kWe or less. To be eligible for support from FiTs, qualifying micro-CHP units must be installed and certified in accordance with the Microgeneration Certification Scheme (MCS). Any other technology and scale of project must be accredited through a process based on the existing Renewable Obligation process, known as the ROO-FIT process. Note that the FiT micro-CHP pilot will support up to 30,000 installations, with a review to start once 12,000 installations are complete.

In order to qualify for the FiT scheme, qualifying CHP generators must be connected to the grid via an import / export meter. FiTs are payable for each unit of electricity generated whether used on-site or exported to the grid. In addition to the generation tariff, any power exported to the grid is also eligible for the export tariff. The tariff rates are adjusted annually by the percentage increase or decrease in the Retail Price Index over the 12 month period ending on 31 December of the previous year.

The Feed-in Tariff does not apply in Northern Ireland and there is no alternative policy in place.

4.2 Policies supporting efficient district heating and cooling

In addition to the various support measures supporting the deployment of CHP as described above, other existing policies provide support for district heating and cooling. These are summarised as follows.

4.2.1 Heat mapping (England, Wales and Northern Ireland)

The government has developed a heat map of England, which helps to identify areas of high heat consumption and potential sources of heat supply. The current heat map shows total heat consumption for public, commercial, industrial and residential buildings. It also shows CHP installations (where data are available) and thermal power stations. The heat map includes layers for heat supply potential from water sources, including rivers, estuaries and the coast.

The heat map was developed to assist local authorities in their initial heat mapping before feasibility studies for potential district heating networks are undertaken. Local authorities are able to obtain the data for their areas to enable them to understand better local heat supply and consumption, and thus assisting them in developing local heat strategies. Using data derived for the National Comprehensive Assessment, heat mapping has been extended to Wales and Northern Ireland. Scotland has its own heat map (see section 4.3.2).

4.2.2 Heat network innovation competition (UK)

Eight innovative heat network projects are being tested across the UK as part of the government's Heat Network Small Business Research Initiative competition. The projects, which include the using of smart systems to diagnose performance issues, combining solar thermal and a large scale heat pump on a heat network, and demonstrating the potential for single well deep geothermal heat to be used in smaller scale heat networks, are each receiving a share of £6 million of funding.

4.2.3 The Energy Company Obligation (Great Britain)

The Energy Company Obligation (ECO) is a government scheme that obliges larger energy suppliers to deliver energy efficiency measures to domestic premises in Great Britain. In respect to district heating (DH), the following measures are eligible under ECO:

- new connections to domestic premises, from new or existing district heating;
- upgrades of existing DH where substantial replacement work is carried out to the plant and/or pipework; and
- the installation of heat meters to existing connections.

4.2.4 Licence Lite (Great Britain)

The energy markets regulator for Great Britain, Ofgem has put in place arrangements to enable smaller scale electricity generators to gain better access to the electricity supply market and obtain a higher price for their power. This new kind of licence relieves the electricity supplier from being party to various industry codes which are too costly and complex for small players. Obtaining a good price for the electricity produced in CHP plants that provide heat to networks can be critical to the viability of networks.

4.2.5 Planning policy

Local authorities are encouraged to consider low carbon and renewable heat networks through the National Planning Policy Framework. The framework encourages local planning authorities to identify opportunities where developments can draw energy supplies from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers.

Scotland
See section 4.3.3

Wales
Within the UK the Town and Country Planning system is devolved to Wales. The Welsh Government, through Planning Policy Wales[36], states that local planning authorities (LPAs) should facilitate the

[36] http://gov.wales/topics/planning/policy/ppw/?lang=en

development of all forms of renewable and low carbon energy to move towards a low carbon economy to help tackle the causes of climate change. On heat it specifically advises that LPAs should seek to maximise the opportunities for district heating and generation schemes in their development plan by co-locating new proposals and land allocations with existing developments and heat suppliers.

To facilitate further consideration of heat potential in planning policies, the Welsh Government published a toolkit for planners in 2010 (updated in 2015) which outlines a methodology to undertake heat mapping at a local level to identify opportunities for potential heat networks[37]. The toolkit also sets out potential policy options for local planning authorities including those which support District Heat Networks.

Northern Ireland

The Strategic Planning Policy Statement for Northern Ireland (SPPS) – Planning for Sustainable Development states that the planning system in NI should consider the energy and heat requirements of new developments when designating land for new residential, commercial and industrial development and make use of opportunities for energy and power sharing, or for decentralised or low carbon source of heat and power wherever possible. The SPPS also encourages promotion of the use of energy efficient, micro-generating and decentralised renewable energy systems.

4.2.6 Heat customer protection scheme (UK)

There has until recently been no standardisation in the quality and level of protection for household customers who receive heat from heat networks. Consumer groups have raised concerns about this issue, and if not addressed it could have a detrimental effect on the growth of the sector.

Collaboration between industry, consumer groups and government has resulted in a voluntary heat customer protection scheme known as Heat Trust[38]. Heat Trust was launched on 25 November 2015 and establishes a common standard in the quality and level of protection given by heat supply contracts and offers heat network customers an independent process for settling disputes. The scheme aims to provide customers with comparable protections to those available, in statute, to gas and electricity customers.

4.2.7 Development of technical standards (UK)

Many good quality sets of guidance on technical issues have been produced by various parties. There are two relatively recent publications of particular importance.

In February 2013 the Greater London Authority's DEPDU published the District Heating Manual for London[39] which contains (inter alia) principles of heat network design, heating standards and construction.

On 10 July 2015, the Chartered Institution of Building Services Engineers (CIBSE) and the Association for Decentralised Energy (ADE) (formerly the Combine Heat and Power Association) launched a technical Code of Practice for heat networks in the UK[40]. The Code has been produced to support the aim of heat networks being designed, built and operated to a high quality to deliver customer satisfaction by raising standards right across the supply chain in the UK. Setting minimum (and best practice) standards should provide greater confidence for specifiers and developers. The Code can also be included in the tendering/contracting process to specify minimum requirements for a project.

4.2.8 Capital funding and financial incentives

Access to capital funding represents a significant barrier to local authorities realising heat network projects that appear commercially viable. Government provides a number of streams of capital funding that can help authorities and developers realise more schemes.

Green Investment Bank (UK)

CHP and Heat Networks are a sub-sector of the Green Investment Bank (GIB) Non Domestic Energy Efficiency Strategy and the bank is keen to support the government by providing advice on policies and programmes to help bring forward commercially developed schemes. The GIB may have a role to play in supporting commercial banks in the funding of these schemes.

[37] http://gov.wales/topics/planning/policy/guidanceandleaflets/toolkitforplanners/?lang=en
[38] http://www.heatcustomerprotection.co.uk/
[39] http://www.londonheatmap.org.uk/Content/Manual.aspx
[40] http://www.cibse.org/knowledge/cibse-other-publications/cp1-heat-networks-code-of-practice-for-the-uk

Infrastructure UK (UK)

Infrastructure UK (IUK) has a remit to provide a stronger focus on the UK's long-term infrastructure priorities and meet the challenge of facilitating significant private sector investment over the longer term. The UK Guarantees scheme aims to kick-start critical infrastructure projects that may have stalled because of adverse credit conditions. Around £40 billion of projects could qualify for the provision of guarantees.

European Regional Development Fund (England and Wales)

Government will continue to explore the potential for allowing the use of low carbon funding under the European Regional Development Fund to be made available for heat networks during the period 2014-2020 by Local Enterprise Partnerships (LEPs) in their EU Investment Strategies in England and Wales. The Scottish Government has established the Low Carbon Infrastructure Transition Programme (see section 4.3.5 below).

Green Growth Wales – Options for investment support (Wales)

The Welsh Government has recently launched a consultation on the potential to provide access to innovative financial provision for energy efficiency and generation projects in Wales[41].

Heat Networks Investment Support (England and Wales)

As part of the Spending Review (SR) announcement of 25 November 2015, the Chancellor confirmed that over £300m of funding would be made available over the SR period to support up to 200 new heat networks in England and Wales. This will include recovering heat from industrial processes and transporting it to homes and businesses. Further details have not yet been released.

4.2.9 Heat Networks Delivery Unit (England and Wales)

Local authorities have a vital role in developing heat networks; as sponsor, pivotal heat customer, heat source, planning authority and relationship brokers. Recognising the capacity and capability challenges which local authorities identified as barriers to heat network deployment in the UK, the Heat Network Delivery Unit (HNDU) was established by the Department of Energy and Climate Change to provide grant funding and guidance to local authorities in England and Wales.

The HNDU is staffed by experts, who have gained experience developing heat networks outside the civil service working on technical or commercial aspects of heat networks for consultancies or local authorities.

The HNDU supports local authorities through the following stages:

1. Heat mapping
2. Energy master planning
3. Feasibility study
4. Detailed project development

Local authorities apply for HNDU support through bidding rounds, of which there have been four to date through which £9.7 million of funding has been awarded. All bids are reviewed by a panel of engineering, financial and commercial experts with significant experience in heat networks development. Grant funding of no more than 67% of eligible costs is provided to successful local authorities. Eligible costs are defined as externally commissioned consultancy costs for heat network development work.

HNDU is designed to ensure that the projects it supports achieve a commercially viable threshold. The Green Investment Bank (GIB) and others provide guidance to HNDU on the criteria that it and other commercial lenders and equity providers would require to invest in projects. This helps to provide a benchmark by which to judge the commercial attractiveness of projects.

4.2.10 Supporting the longer-term development of heat networks

The government is also taking forward a number of areas of work to address longer term institutional challenges to the wider deployment of heat networks.

[41] http://gov.wales/consultations/environmentandcountryside/green-growth-wales-options-for-investment-support/?lang=en

Innovation (UK)

In 2012 a Technology Innovation Needs Assessment for heat[42] identified heat network technologies that are of high to medium priority for innovation support by government where this is unlikely to come from other sources. The assessment highlighted three main areas for investigation: some core components and processes required for heat network development, for example smart controls; low carbon heat sources for use with networks, such as large-scale heat pumps; and storage solutions that can help networks manage supply and demand intermittency.

Access and connection rights (England and Wales)

The government will continue to explore what access rights heat network providers have in other EU member states, including whether they have statutory undertaker powers, to assess whether there are any lessons that could be applicable to England and Wales in the future.

Statutory powers similar to those available to electricity and gas utilities could make it easier for developers and operators to gain access to land to build and maintain their networks, and gain access to premises of consumers in connection with their supply of heat. It would not be appropriate to pursue this unless there is demand from the industry itself and the Government would want to take views from a wide range of stakeholders.

Similarly, the growth of heat networks at the scale described earlier in this chapter will involve growth through interconnection between networks and the introduction of new heat sources to expanding heat networks as well as new heat loads. As utility infrastructure in the form of physical networks is a monopoly asset, it is subject to regulation to enable connections to take place where the capacity is available. The UK government does not see the need for the introduction of such regulation for heat networks at this stage, but it will assess these issues to establish whether they emerge as significant barriers as heat networks grow.

Heat Networks (Metering and Billing) Regulations (UK)

The Heat Network (Metering and Billing) Regulations 2014 came into force last December to implement the metering and billing articles of the Energy Efficiency Directive throughout the UK, as they apply to heating and cooling. Articles 9(1) & (3) of the Directive impose metering requirements on district heating, district cooling and communal heating/hot water systems. Articles 10 and 11 introduce requirements on billing information and the costs of access to billing information. In certain circumstances the installation of meters is a mandatory requirement. These are where a new district heating or district cooling connection is made to a newly constructed building, where a building on a district heating network undergoes a major renovation or at a building-level where buildings have more than one final customer. In all other circumstances and for all buildings, individual meters must be installed where it is cost effective and technically feasible to do so. The National Measurement and Regulation Office (NMRO) is the enforcing authority for the regulations. The regulations include a requirement for heat suppliers to notify the NMRO with details of their networks[43].

[42] http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/heat/

[43] Further information is available at https://www.gov.uk/guidance/heat-networks

4.3 Relevant policy measures specific to Scotland

In Scotland there are a number of programmes and policies which support energy efficiency in the non-domestic and public sectors and CHP can be considered within these programmes. These include Resource Efficiency Scotland, Salix Finance and the public sector non-domestic energy efficiency procurement framework.

Business and industry

Resource and demand reduction is supported in business and industry through investing annually into the Scottish Government's £9.3 million Resource Efficient Scotland programme and SME loan scheme. The programme offers information, advice and support to private, public and third sector organisations to implement energy, material resource and water efficiency measures. Since April 2013, it has delivered advice and support to over 33,000 organisations to realise over £49 million and 910 GWh worth of lifetime energy savings through the application of better resource efficiencies. The Resource Efficient Scotland programme is focusing efforts on Scotland's nine most energy and heat intensive sectors to develop a programme of advice and support for decarbonisation, energy efficiency and heat recovery. Funding for the Resource Efficient Scotland SME loan scheme was increased by £1.5 million in 2015/16.

The public sector

The Scottish Government provides financial support for public bodies through the Salix loans scheme to help fund energy efficiency projects encouraging uptake of low carbon technologies and stimulating wider investment in energy efficiency.

Scottish Public Sector Bodies have a key leadership role to play through the actions they take on their own estates to minimise heat demand, as well as identifying opportunities for utilising unused excess heat. Developing energy efficiency programmes of scale across the public sector will facilitate efficiencies, such as in procurement, and through identification of a pipeline of projects encouraging the development of the associated supply chain in Scotland. The Scottish Government is developing in partnership with public sector representatives, a non-domestic energy efficiency (NDEE) procurement framework for the Scottish public sector. By late 2015 this will allow public bodies to procure estate wide energy efficiency works. Stakeholder engagement to date indicates that the total value of projects going through the NDEE framework could be in the range of £250-300 million within the next four years. The procurement framework allows for small scale generation and district heating where this is part of a package of wider energy efficiency measures.

Heat policy is a devolved matter and over the last few years the Scottish Government has been developing its approach to heat policy culminating in the publication of a Heat Policy Statement in June 2015[44]. The Heat Policy Statement sets out the actions currently being taken and planned by the Scottish Government on heat including those relating to heat transmission and storage, and confirms the Scottish Government's ambition to achieve 1.5 TWh of Scotland's heat consumption to be delivered by district or communal heating and to have 40,000 homes connected by 2020.

In 2012, the Expert Commission on District Heating, convened by the Minister for Business, Energy and Tourism, reported to the Scottish Government with a range of recommendations to accelerate the uptake of district heating across Scotland. The Scottish Government District Heating Action Plan[45] published in June 2013 set out the actions the Scottish Government proposed to take in response to the Expert Commission's recommendations and in June 2015 published a summary update[46] identifying that 19 of the 23 actions had been completed, with the remaining actions ongoing or under review. Many of the following measures were identified as actions under the plan or identified in the Heat Policy Statement.

Historically, the scale of the market has not been sufficient to require regulatory intervention. However, as more homes and businesses connect it is important to ensure that existing and potential consumers have confidence that the supply is reliable and bills are transparent. As the market grows, the Scottish Government plans to develop appropriate regulation, commensurate with the scale of the heat market, ensuring both consumer protection and further industry development. The Scottish Government has

[44] http://www.gov.scot/Publications/2015/06/6679/downloads

[45] http://www.gov.scot/Publications/2013/06/7473

[46] http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/Heat/ProgressDHAP

established the Special Working Group of the Expert Commission on District Heating to consider potential regulatory frameworks for district heating and provide advice. The Scottish Government will consider these recommendations working with industry and heat user representatives to develop any further regulations in such a way that they support development and do not act as a barrier at this early stage in the growth of the heat supply market, nor place excessive costs on the sector that could be passed on to consumers.

4.3.1 Heat Network Partnership for Scotland

The Scottish Government established the Heat Network Partnership for Scotland (HNP) in 2013 to co-ordinate support for district heating development across a number of agencies and programmes: Scottish Enterprise, Scottish Futures Trust, the Energy Saving Trust, Resource Efficient Scotland and the Stratego project, funded by Intelligent Energy Europe and the Scottish Government. The Heat Network Partnership has contributed over £300,000 toward feasibility studies and options appraisals for potential district heating projects. The Heat Network Partnership website (www.districtheatingscotland.com) gives details of where project developers can obtain support and forms a hub of information on district heating in Scotland. It contains a wide range of tools and guidance along with examples of best practice covering leadership, procurement, technology, planning and finance for district heating schemes.

Local authorities have a key role to play in the planning and development of heat networks. Without a robust district heating strategy and process in place, local authorities are at risk of adopting a piecemeal, reactive approach to individual energy supply opportunities which fail to realise the full environmental and economic benefits of a single integrated system. The HNP's District Heating Strategy Support Programme has provided a programme of support that guides participating local authorities through the process of developing a district heating strategy and has utilised the expertise of the various support agencies, as well as providing a forum for sharing knowledge and experience.

Project development support is also being provided from the Low Carbon Infrastructure Transition Programme (LCITP). The LCITP is a working partnership between the Scottish Government, Scottish Enterprise, Highlands & Islands Enterprise, Scottish Futures Trust and sector specialists. This partnership is supported by the new 2014-2020 European Regional Development Fund (ERDF) programme. The intervention will focus on supporting the acceleration of projects to develop investment grade business cases allowing them to secure existing streams of public and private capital finance. With £76 million over the first three years, the ambition is to provide an integrated programme of advice and support to over 100 low carbon projects.

4.3.2 Heat mapping

In order for local authorities and other stakeholders to gain a greater understanding of the heat demand and supply needs across Scotland the Scottish Government developed the Scotland Heat Map with data provided by Scottish public sector organisations. Data sets have been provided to all Scottish local authorities and a web version of the heat map is available which allows the user to produce a report which can be downloaded for a specific geographic area either set by the user or using standard geographies such as local authority, settlement or data zone.[47]

4.3.3 The planning system

Scotland's third National Planning Framework (NPF3) and Scottish Planning Policy (SPP), published in June 2014, provide the national planning policy context for delivering heat networks. Both strongly support the roll-out of heat networks and development of renewable energy. In particular the SPP states that local development plans should:

- support new build developments, infrastructure or retrofit projects which deliver energy efficiency and the recovery of energy that would otherwise be wasted both in the specific development and surrounding area.
- use heat mapping to identify the potential for co-locating developments with a high heat demand with sources of heat supply. Heat supply sources include harvestable woodlands, sawmills producing biomass, biogas production sites and developments producing unused excess heat, as well as geothermal systems, heat recoverable from mine waters, aquifers, other bodies of

[47] Further information including a user guide and access to the map is available at: http://www.gov.scot/heatmap

water and heat storage systems. Heat demand sites for particular consideration include high density developments, communities off the gas grid, fuel poor areas and anchor developments such as hospitals, schools, leisure centres and heat intensive industry.

- support the development of heat networks in as many locations as possible, even where they are initially reliant on carbon-based fuels if there is potential to convert them to run on renewable or low carbon sources of heat in the future. Local development plans should identify where heat networks, heat storage and energy centres exist or would be appropriate and include policies to support their implementation. Policies should support safeguarding of pipe-runs within developments for later connection and pipework to the curtilage of development. Policies should also give consideration to the provision of energy centres within new development. Where a district network exists, or is planned, or in areas identified as appropriate for district heating, policies may include a requirement for new development to include infrastructure for connection, providing the option to use heat from the network.

4.3.4 District Heating Loan Fund

The District Heating Loan Fund offers low interest unsecured loans for both district heating low carbon and renewable technology projects in Scotland. The loans, typically up to £400,000 per project, help overcome a range of infrastructural issues and the costs of developing these projects. The loans are repaid over a period of up to 10 years at, for low risk projects, an interest rate of 3.5%. The scheme is open to local authorities, registered social landlords, small and medium sized enterprises and energy services companies (ESCOs) with fewer than 250 employees.

In March 2014 funding for the District Heating Loans Fund was increased by over £4 million, making a total of £8 million available over the two years 2014 to 2016. Since 2011, the total commitment to the District Heating Loans Fund is over £11 million, with around £7 million committed to date to 33 projects, 17 of which are now fully commissioned. In February 2015, the Scottish Government the award of announced £2.7 million for 12 projects and that applications from large-scale projects for loans greater than £400,000 would be considered on a case by case basis. The first enhanced loan of £1 million has been awarded to Aberdeen Heat and Power.

4.3.5 Cross cutting schemes

The following schemes are not specifically targeted at district heating but may support it.

The **Low Carbon Infrastructure Transition Programme** (LCITP), supported by European Structural Funds, was launched on 20 March 2015. The LCITP is a Scotland-wide, collaborative cross-sector project development unit with the aim of accelerating the number of low carbon infrastructure projects in Scotland to investment readiness stage. The intervention focuses on supporting the acceleration of projects to develop investment grade business cases allowing them to secure existing streams of public and private capital finance. With £76 million over the first three years, the ambition is to provide an integrated programme of advice and support to over 100 low carbon projects[48]. As an example during autumn 2015 the LCITP held a Water Source Heat Pump challenge fund to accelerate the delivery of large scale water source heat pump projects supporting district heating schemes in Scotland through the provision of renewable heat.

The **Local Energy Challenge Fund** (LECF) was announced in October 2014. It is a £20 million fund offered under the Community and Renewable Energy Scheme (CARES) to demonstrate the benefit of integrating low carbon energy sources in local energy systems. District heating schemes have been awarded funding through this scheme.

[48] Further information including eligibility criteria and project stages can be found at: http://www.gov.scot/Topics/Business-Industry/Energy/Action/lowcarbon/LCITP

4.4 High-efficiency CHP and progress achieved under Directive 2004/8/EC

The UK's CHP Quality Assurance programme (CHPQA) is the major source for UK CHP statistics, with Good Quality (GQ) CHP denoting schemes that have been certified as being highly efficient through the programme.

The criteria used are in line with the requirements for high efficiency CHP set down in the Energy Efficiency Directive (2012/27/EU) and previously under the CHP Directive 2004/8/EC. A Good Quality CHP scheme, with installed capacity of 1 MWe or above, must achieve primary energy savings of at least 10% compared with the EU reference values for the separate generation of heat and power.

An indication of progress achieved under the CHP Directive is shown in the Figure 4.1 which shows operating CHP capacity since the year 2000 for CHP schemes certified under CHPQA and how underlying market activity has replaced older capacity as it is taken out of service over time. The dotted line shows how much of the Good Quality CHP capacity that was in place in 2000 remained in place in subsequent years, while the upper line shows the actual Good Quality CHPQA capacity in place in each year.

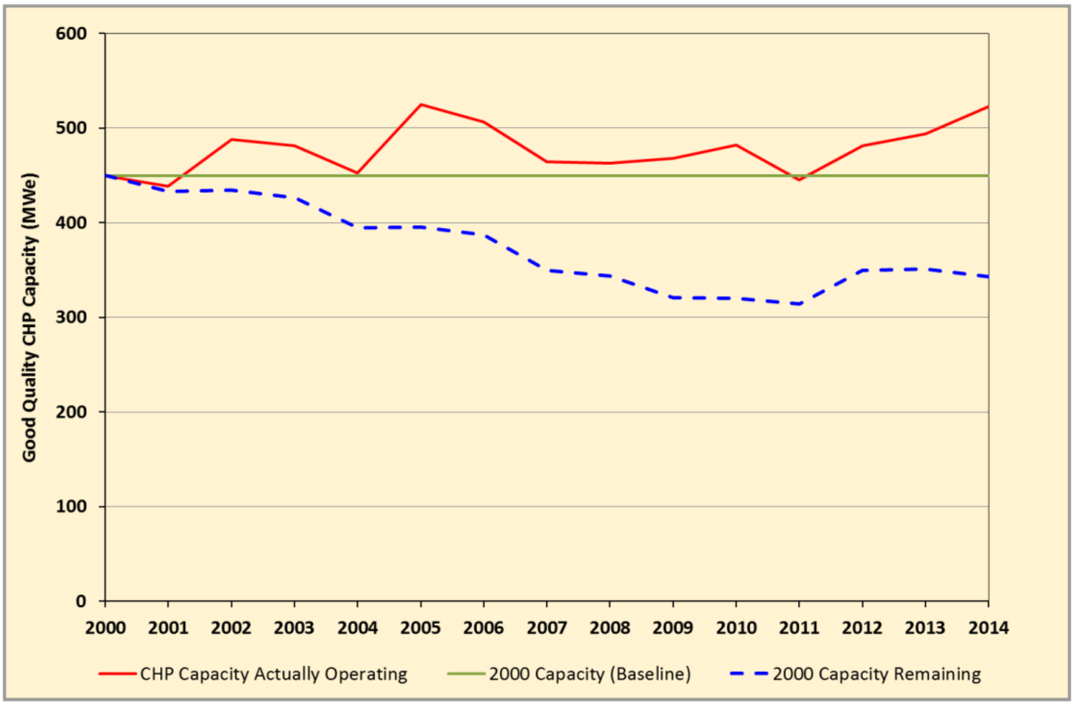


Figure 4.1: Underlying UK CHP market activity – operating Good Quality CHP versus retained Good Quality CHP[49]

For any year since 2000, the gap between these two lines represents the new Good Quality CHPQA capacity installed between 2000 and that year. By 2014 there had been just over 3.0 GWe of new Good Quality CHPQA capacity installed since 2000. Modelling[50] suggests cost effective potential for 18 GWe CHP capacity in the UK by 2020, excluding CHP known to have been in operation in 2014, this represents around three times current UK GQCHP capacity.

[49] https://www.gov.uk/government/statistics/combined-heat-and-power-chapter-7-digest-of-united-kingdom-energy-statistics-dukes

[50] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191543/Projections_of_CHP_capacity___use_to_2030_2204.pdf

Glossary

Absorption cooling

Refrigeration plant driven by heat rather than a mechanical compressor. Absorption cooling uses an absorbent as a secondary fluid to absorb the primary fluid, which is a gaseous refrigerant in the evaporator. The evaporative process absorbs heat, thereby cooling the refrigerant which in turn cools the chilled water circulating through the heat exchanger.

Built-up areas (BUA)

Created as part of the 2011 Census outputs, provides information on the villages, towns and cities where people live, and allows comparisons between people living in built-up areas and those living elsewhere. The definition follows a "bricks and mortar" approach, with BUAs defined as land with a minimum area of 20 hectares (200,000 square metres), while settlements within 200 metres of each other are linked.

http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/built-up-areas---built-up-area-sub-divisions/index.html

Censuses

The UK Census, undertaken every 10 years, with the most recent being on 27 March 2011, collects population and other statistics essential to those who have to plan and allocate resources. The main geographies directly associated with the Census are **output areas (OA)** and **super output areas (SOA). OAs** are the base unit for Census data releases. The 5,022 **Census Output Areas** represent the smallest geographic units for which robust statistics can be produced while protecting the confidentiality of individual Census returns, each have an average size of around 150 households. Super output areas (SOA), lower layer super output areas (**LSOA**) and middle layer super output areas (**MSOA**), designed to improve the reporting of small area statistics and are built up from groups of output areas (OA).

http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html

Combined Heat & Power Quality Assurance Programme (CHPQA)

CHPQA is an initiative by the Government to encourage the wider practical application of Good Quality Combined Heat and Power, Community Heating and Alternative Fuel technologies. CHPQA aims to monitor, assess and improve the quality of UK Combined Heat and Power. Certification issued under CHPQA may be used for determining the eligibility of Schemes for fiscal or other benefits and for determining compliance of Schemes with regulatory requirements where quality is relevant to entitlement. The CHP **Qualifying Power Capacity** (QPC) is the registered power generation capacity of a CHP Scheme (MWe) that qualifies as Good Quality CHP. It is used for monitoring the installed capacity of Good Quality CHP in the UK.

https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme

Cooling

See 'Heat'

Demand

Demand in the context of an energy requirement can mean either:

- the instantaneous demand, which is the rate of energy flow expressed in units such as joules/sec (J/s), kilowatts (kW) or megawatts (MW); or
- the consumption of energy over a specified period of time, which is a quantity of energy expressed in units such as joules (J), kilowatt hours (kWh) or megawatt hours (MWh).

District heating and cooling

The provision of heating and/or cooling to multiple buildings from centralised plant via a network of pipes. Communal systems (i.e. systems serving multiple heat consumers in a single building) have not been modelled due to the availability and reliability of data.

Energy Consumption in the United Kingdom' (ECUK)

ECUK is an annual statistical publication that provides a comprehensive review of energy consumption and changes in efficiency, intensity and output since the 1970s, with a particular focus on trends since 2000.

https://www.gov.uk/government/collections/energy-consumption-in-the-uk

Kilowatt hours, megawatt hours, gigawatt hours and terawatt hours

These are common units of energy and respectively have the symbols: kWh, MWh, GWh and TWh.

A kilowatt hour is equal to 3.6 mega-joules; i.e. 3,600,000 J.

A megawatt hour is 1,000 kWh

A gigawatt hour is 1,000 MWh

A terawatt hour is 1,000 GWh

Good Quality CHP

See Combined Heat & Power Quality Assurance Programme

Heat

Heat is the energy transferred between materials as a consequence of a difference in their temperature. Heating and cooling are simply two sides of the same coin; heating of an object is the supply of heat energy to it, cooling of an object is the removal of heat energy from it.

Intermediate zones (IZ) in Scotland

A geography used for small-area reporting in Scotland, built from clusters of data zones and fit within council area boundaries, each contains at least 2,500 residents.

http://www.gov.scot/Publications/2005/02/20732/53081

Long-run variable costs of energy supply (LRVC)

See:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360044/2014_Background_Documentation_to_DECC_HMT_Supplementary_Appraisal_Guidance.pdf

National Atmospheric Emissions Inventory (NAEI)

The NAEI is funded by DECC, Defra, The Welsh Government, The Scottish Government and The Department of Environment, Northern Ireland. The NAEI compiles estimates of emissions to the atmosphere from UK sources such as cars, trucks, power stations and industrial plant. These emissions are estimated to help to find ways of reducing the impact of human activities on the environment and our health.

http://naei.defra.gov.uk/

Net Present Value (NPV) analysis

The NPV is the discounted value of a stream of either future costs or benefits and is the term used to describe the difference between the present value of a stream of costs and a stream of benefits.
A discount rate is used to convert all costs and benefits to 'present values', so that they can be compared.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

Nomenclature of Territorial Units for Statistics (NUTS)

NUTS was created by the European Office for Statistics as a single hierarchical classification of spatial units used for statistical production across the European Union. At the top of the hierarchy are the individual member states; below that are levels 1 to 3. There are 12 NUTS 1 areas in the UK, for example North West (England) is one with the NUTS1 code 'UKD'.

http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/eurostat/index.html

Output Area (OA)

OAs are the lowest level of statistical unit in England and Wales, with an average population of approximately 300 people.

Settlements (Northern Ireland)

Settlements in Northern Ireland are statistically classified and delineated by settlement development limits (SDLs), defined by the Planning Service. SDL boundaries are available for settlements with a population of greater than 1000.

http://www.nisra.gov.uk/geography/UrbanRural.htm

Settlements (Scotland)

National Records of Scotland (NRS) produces small area population estimates at data zone level (areas with approximately 500-1000 household residents) and these, together with information from the Royal Mail Postcode Address File, are used to classify unit postcodes as either 'high density' or 'low density'. The population estimates in contiguous high density postcodes are joined together to form the built-up areas of Scotland. Where the population is 500 or more, the area is defined as a 'settlement'. Localities are intended to be more representative of the towns and cities in Scotland.

http://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/special-area-population-estimates/settlements-and-localities/background-information

Small Areas (Northern Ireland)

SAs were introduced in Northern Ireland after the 2011 Census. Small Areas are generally created by amalgamating 2001 Census Output Areas which were built from clusters of adjacent postcodes. Small Areas nest within the 890 Super Output Areas and the 582 Electoral Wards in Northern Ireland. There are 4,537 SAs in Northern Ireland.

http://www.nisra.gov.uk/geography/SmallAreas.htm

Technical potential

The technical potential where the technology is technically feasible. The technical potential (of a particular solution) therefore represents a maximum technically possible deployment of the technology irrespective of costs.

Unique Property Reference Number (UPRN)

The UPRN is the unique identifier for every spatial address in Great Britain, providing a consistent identifier throughout a property's life cycle, contains no attribution or information about the property.

http://www.ordnancesurvey.co.uk/about/governance/policies/addressbase-uprn.html

Updated energy projections (UEPs)

Each year DECC publishes UEPs, analysing and projecting future energy use and greenhouse gas emissions in the UK that are based on assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables regularly updated. Each set of projections takes account of climate change policies where funding has been agreed and where decisions on policy design are sufficiently advanced to allow robust estimates of policy impacts to be made.

https://www.gov.uk/government/collections/energy-and-emissions-projections

Wards (Northern Ireland).

SOAs have been created in Northern Ireland on an electoral ward-by-ward basis taking into account measures of population size and mutual proximity. NI SOAs should have population counts that fall between a lower threshold of 1300 and an upper threshold of 2800, with a target size of circa 2000. Where the Ward population exceeded the upper threshold, the ward is split.

http://www.nisra.gov.uk/deprivation/super_output_areas.htm

Appendices

Appendix 1: Results and heat maps by devolved administration and English region

Appendix 2: Methodology

Appendix 3: Assumptions

Appendix 4: Data sources

Appendix 1: Results and heat maps by devolved administration and English region

Wales

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**28**	**10**	**1**	**2**	**15**
Heat only gas/oil boilers	26	9	1	2	14
Electric heating	2	1	0	0	1
Gas CHP and backup boilers	1	1	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	23	9	1	2	11
	Biomass CHP + gas boilers	8	7	0	0	
	Biomass boilers	19	8	0	1	11
	Air to water heat pumps	17		1	2	14
	Ground source heat pumps	14		1	2	11
	Solar thermal + gas boilers	20		1	2	17
	Solar thermal + biomass boilers	15		0	1	14
District heating	Gas CHP + gas boilers	14		14		
	Biomass CHP + gas boilers	14		14		
	Biomass boiler	14		14		
	Ground source heat pumps	14		14		
	Power station heat	3		3		
	Waste incinerator heat	0		0		
	Industrial waste heat	0		0		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa.

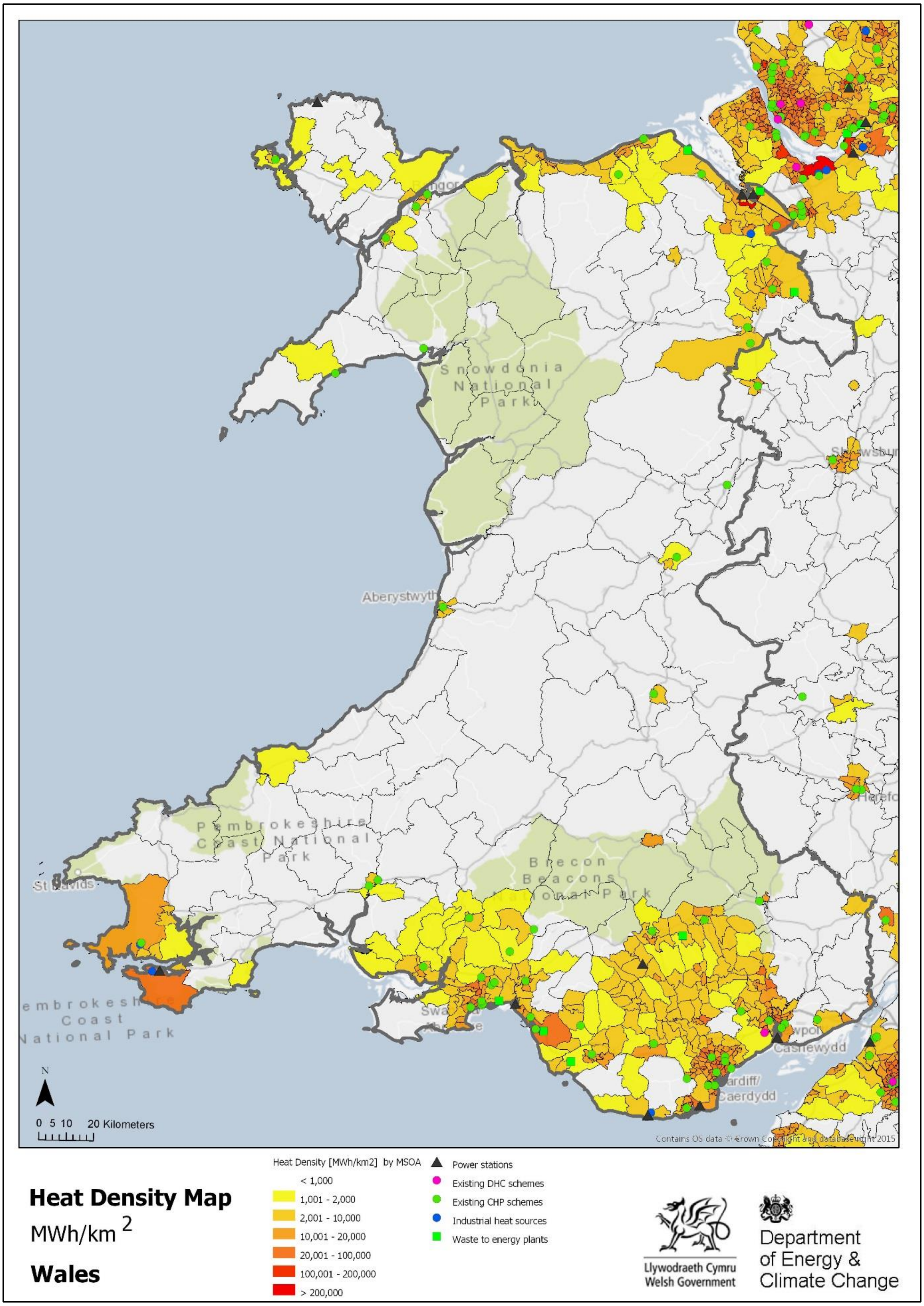
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**11**	**9**	**2**		
Individual	*9*	*9*	*0*	*0*	*0*
District heating	*1*		*1*		
Non-CHP baseline, total	**18**	**2**	**1**	**1**	**15**
Total heat output	**28**	**10**	**18**		

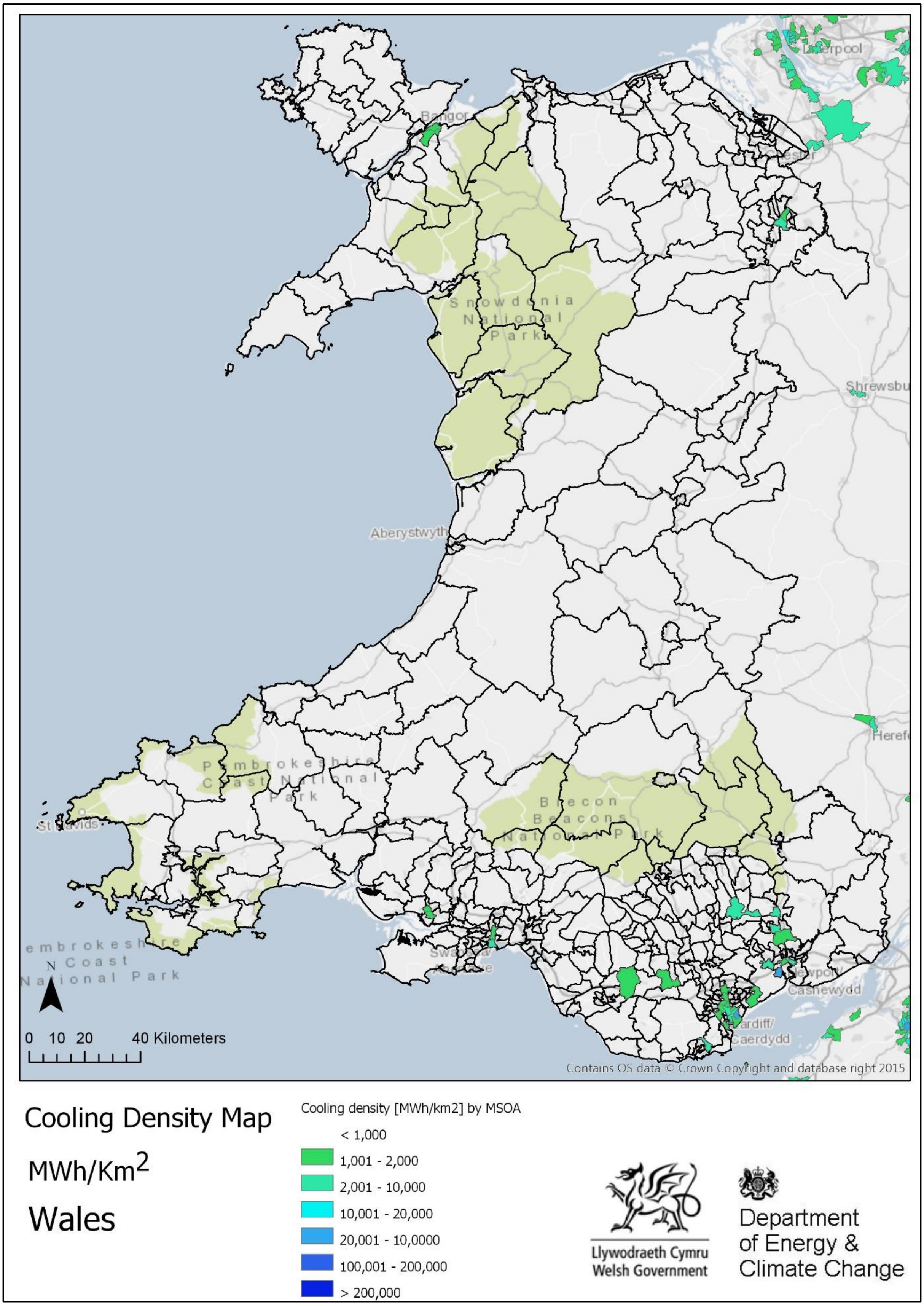
Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**18**	**9**	**9**		
Individual	*10*	*9*	*0*	*0*	*0*
District heating	*9*		*9*		
Non-CHP baseline, total	**11**	**1**	**0**	**0**	**9**
Total heat output	**29**	**10**	**19**		

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**22**	**9**	**13**		
Individual	*14*	*9*	*0*	*0*	*5*
District heating	*8*		*8*		
Non-CHP baseline, total	**7**	**1**	**0**	**0**	**6**
Total heat output	**29**	**10**	**19**		


Snowdonia
National
Park
Aberystwyth
Pembrokeshire
Coast National
Park
Brecon
Beacons
National Park
Casnewydd
Cardiff/
Caerdydd
N
0 5 10 20 Kilometers
Contains OS data © Crown Copyright and database right 2015
Heat Density Map
MWh/km 2
Wales
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Llywodraeth Cymru
Welsh Government
Department
of Energy &
Climate Change


Bangor
Liverpool
Chester
Snowdonia
National
Park
Shrewsbu
Aberystwyth
Heref
Pembrokeshire
Coast National
Park
Brecon
Beacons
National Park
St Davids
embrokeshire
Coast
National Park
N
0 10 20 40 Kilometers
Swansea
Abertawe
Newport
Casnewydd
Cardiff/
Caerdydd
Contains OS data © Crown Copyright and database right 2015
Cooling Density Map
MWh/Km2
Wales
Cooling density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 10,0000
100,001 - 200,000
> 200,000
Llywodraeth Cymru
Welsh Government
Department
of Energy &
Climate Change

Northern Ireland

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**11**	**2**	**0**	**0**	**9**
Heat only gas/oil boilers	11	1	0	0	9
Electric heating	0	0	0	0	0
Gas CHP and backup boilers	0	0	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	3	1	0	0	1
	Biomass CHP + gas boilers	1	1	0	0	
	Biomass boilers	7	1	0	0	6
	Air to water heat pumps	10		0	0	9
	Ground source heat pumps	2		0	0	1
	Solar thermal + gas boilers	12		0	0	11
	Solar thermal + biomass boilers	9		0	0	8
District heating	Gas CHP + gas boilers	1			1	
	Biomass CHP + gas boilers	1			1	
	Biomass boiler	1			1	
	Ground source heat pumps	1			1	
	Power station heat	1			1	
	Waste incinerator heat	0			0	
	Industrial waste heat	0			0	

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

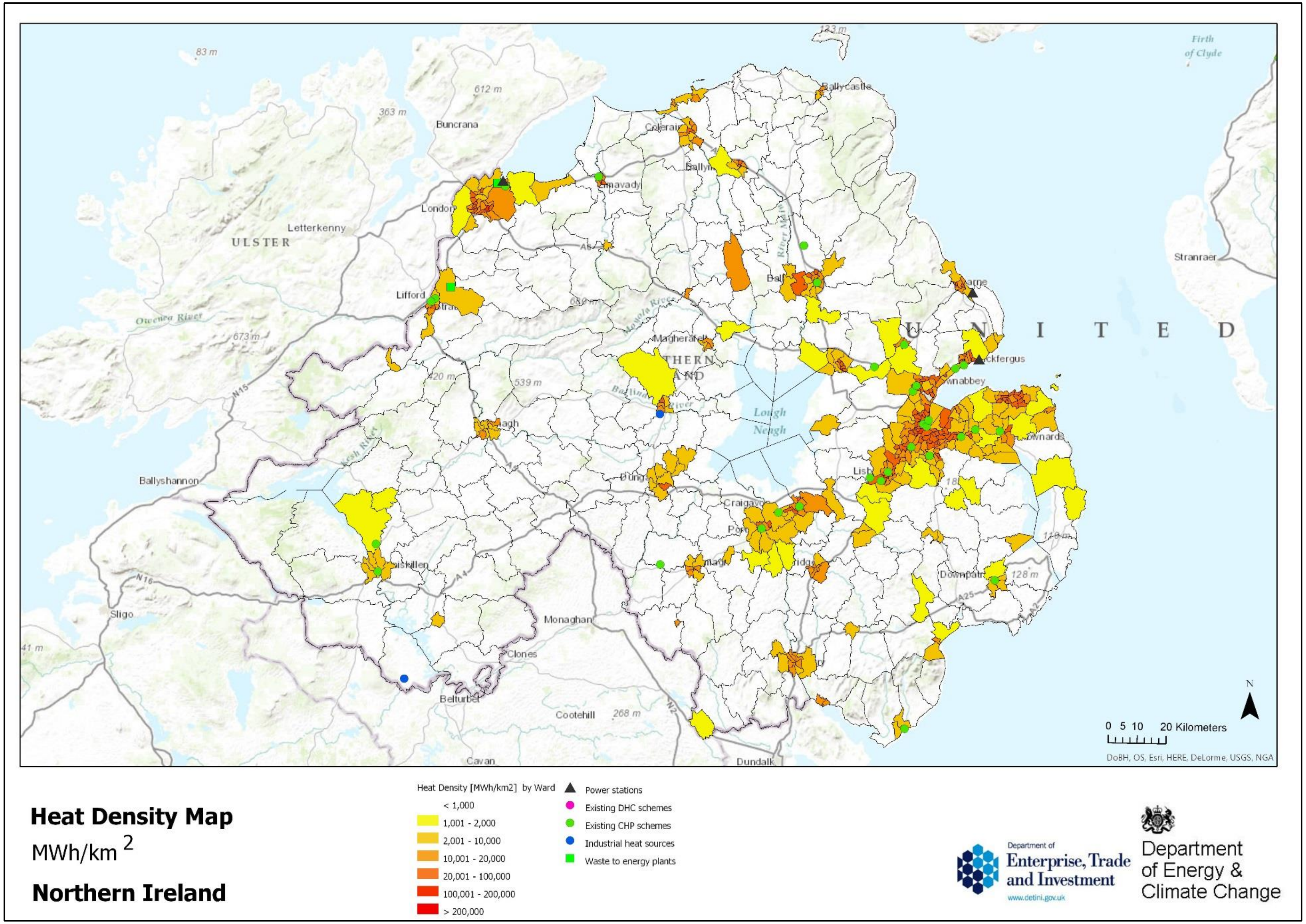
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**2**	**1**	**1**		
Individual	*1*	*1*	*0*	*0*	*0*
District heating	*0*		*0*		
Non-CHP baseline, total	**10**	**1**	**0**	**0**	**9**
Total heat output	**11**	**2**	**10**		

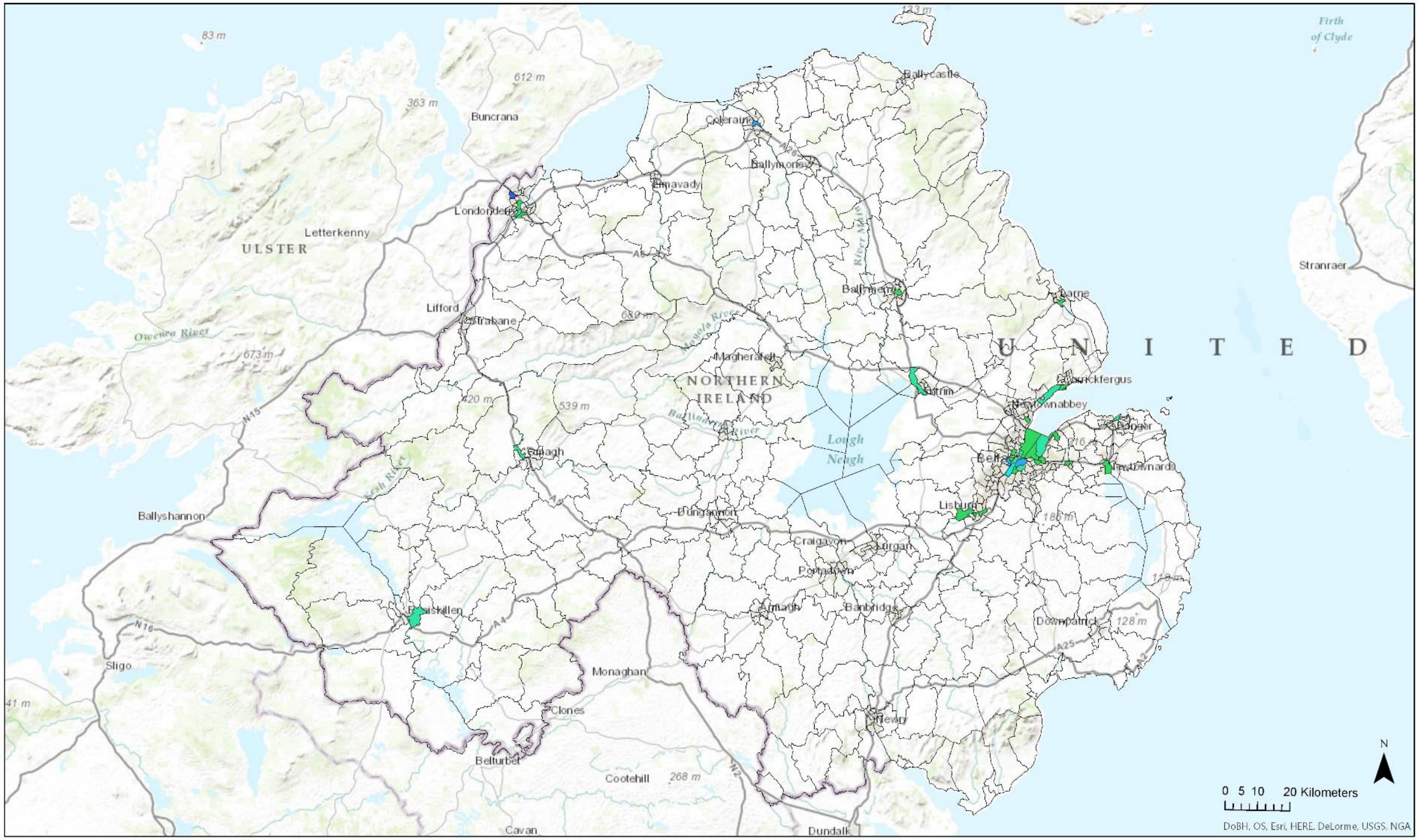
Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**6**	**1**	**5**		
Individual	*5*	*1*	*0*	*0*	*3*
District heating	*1*		*1*		
Non-CHP baseline, total	**5**	**0**	**0**	**0**	**4**
Total heat output	**11**	**2**	**10**		

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**10**	**1**	**8**		
Individual	*8*	*1*	*0*	*0*	*7*
District heating	*2*		*2*		
Non-CHP baseline, total	**2**	**0**	**0**	**0**	**1**
Total heat output	**12**	**2**	**10**		


Heat Density Map
MWh/km 2
Northern Ireland
Heat Density [MWh/km2] by Ward
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
0 5 10 20 Kilometers
DoBH, OS, Esri, HERE, DeLorme, USGS, NGA
Buncrana
Letterkenny
ULSTER
Lifford
Ballyshannon
Sligo
Monaghan
Clones
Belturbet
Cootehill
Cavan
Dundalk
Stranraer
Firth of Clyde
Lough Neagh
Ballycastle
U N I T E D
Department of Enterprise, Trade and Investment
www.detini.gov.uk
Department of Energy & Climate Change



Cooling density [MWh/Km2] by Ward

- < 1,000
- 1,001 - 2,000
- 2,001 - 10,000
- 10,001 - 20,000
- 20,001 - 10,0000
- 10,0001 - 200,000
- > 200,000

Cooling Density Map

MWh/km ^{2}

Northern Ireland

Department of Enterprise, Trade and Investment
www.detini.gov.uk

Department of Energy & Climate Change

England: North East

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**25**	**11**	**1**	**1**	**12**
Heat only gas/oil boilers	23	9	1	1	12
Electric heating	1	0	0	0	0
Gas CHP and backup boilers	1	1	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	23	11	1	1	11
	Biomass CHP + gas boilers	1	1	0	0	
	Biomass boilers	3	1	0	0	3
	Air to water heat pumps	13		1	1	12
	Ground source heat pumps	12		1	1	11
	Solar thermal + gas boilers	14		1	1	12
	Solar thermal + biomass boilers	3		0	0	3
District heating	Gas CHP + gas boilers	13			13	
	Biomass CHP + gas boilers	13			13	
	Biomass boiler	13			13	
	Ground source heat pumps	13			13	
	Water source heat pumps	5			5	
	Power station heat	3			3	
	Waste incinerator heat	0			0	
	Industrial waste heat	0			0	

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

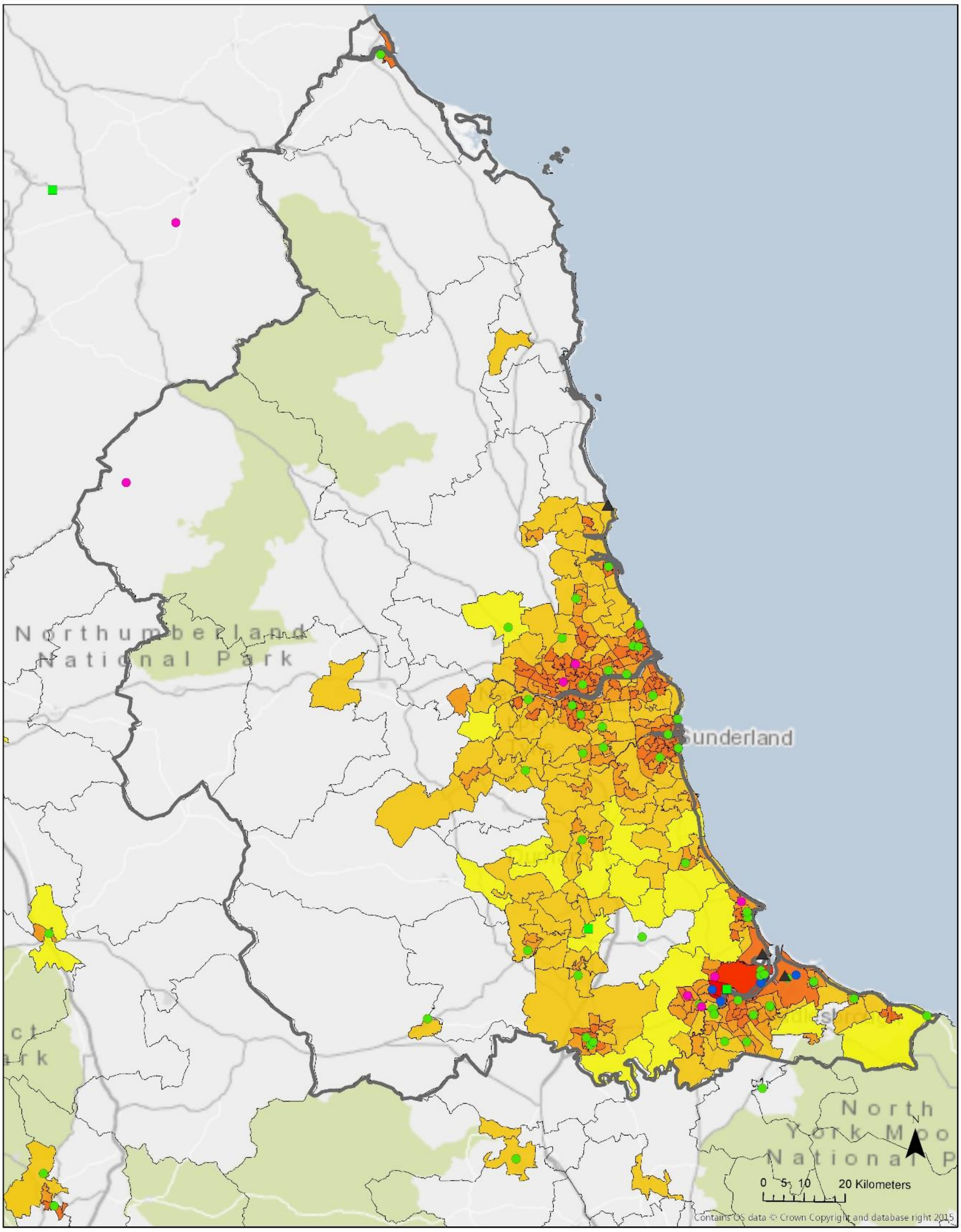
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**10**	**10**		**1**	
Individual	*10*	*10*	*0*	*0*	*0*
District heating	0			0	
Non-CHP baseline, total	**14**	**1**	**0**	**0**	**12**
Total heat output	**25**	**11**		**14**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**16**	**10**			**6**
Individual	*11*	*10*	*0*	*0*	*0*
District heating	*6*			*6*	
Non-CHP baseline, total	**9**	**0**	**0**	**0**	**8**
Total heat output	**25**	**11**		**14**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**19**	**10**		**10**	
Individual	*14*	*10*	*0*	*0*	*4*
District heating	*5*			*5*	
Non-CHP baseline, total	**6**	**1**	**0**	**0**	**4**
Total heat output	**25**	**11**		**14**	



Heat Density Map
MWh/km ^{2}
North East England

England: North West

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**61**	**21**	**4**	**4**	**32**
Heat only gas/oil boilers	55	17	3	4	31
Electric heating	3	1	0	0	2
Gas CHP and backup boilers	3	3	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	57	20	3	4	29
	Biomass CHP + gas boilers	2	1	0	1	
	Biomass boilers	11	1	1	1	8
	Air to water heat pumps	40		3	4	32
	Ground source heat pumps	36		3	4	28
	Solar thermal + gas boilers	40		3	4	32
	Solar thermal + biomass boilers	12		1	1	10
District heating	Gas CHP + gas boilers	37		37		
	Biomass CHP + gas boilers	37		37		
	Biomass boiler	37		37		
	Ground source heat pumps	37		37		
	Water source heat pumps	21		21		
	Power station heat	6		6		
	Waste incinerator heat	0		0		
	Industrial waste heat	1		1		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

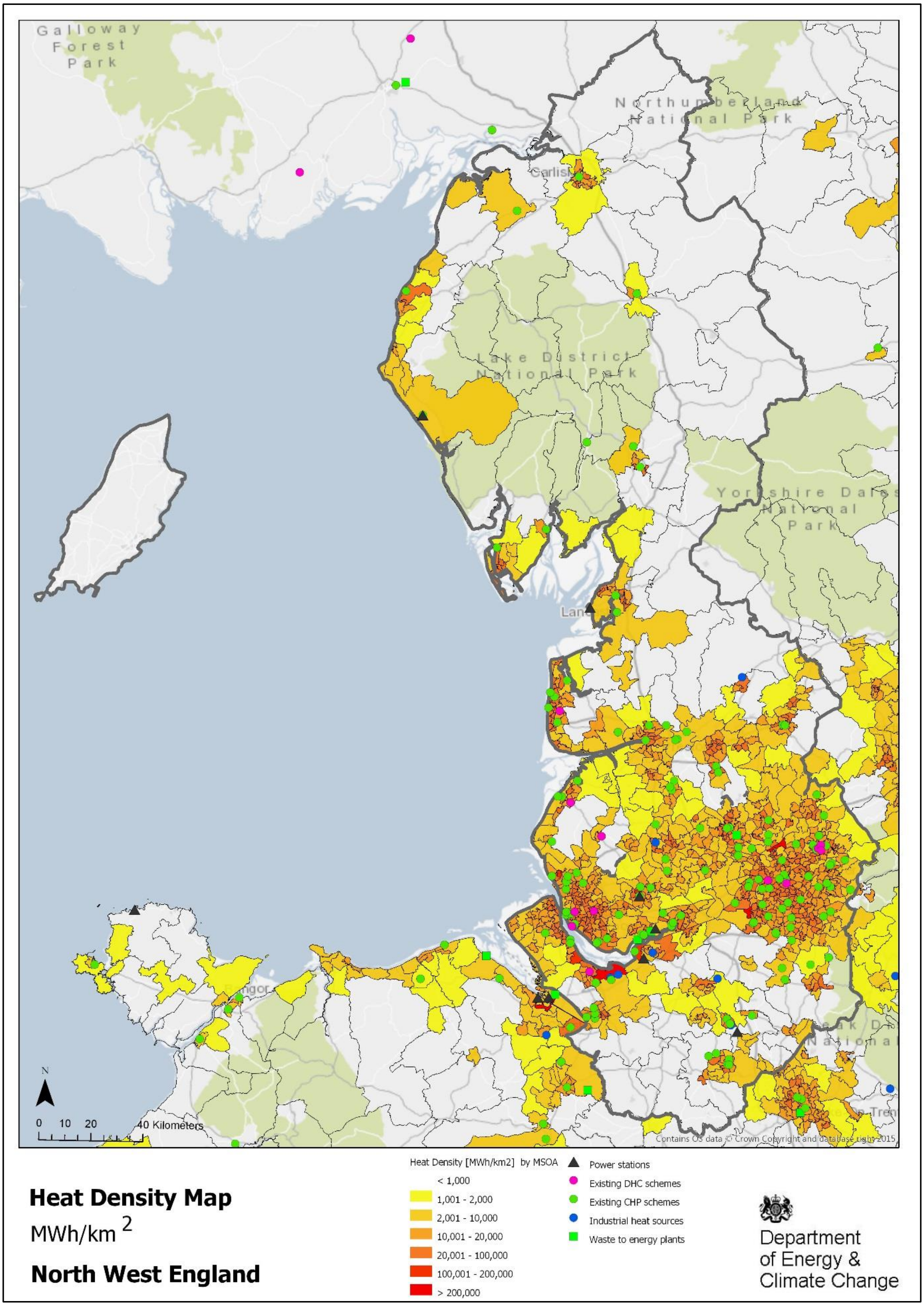
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**23**	**17**		**5**	
Individual	*19*	*17*	*1*	*1*	*0*
District heating	*4*			*4*	
Non-CHP baseline, total	**39**	**4**	**2**	**1**	**32**
Total heat output	**61**	**21**		**41**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**40**	**19**		**21**	
Individual	*20*	*19*	*0*	*0*	*0*
District heating	*19*			*19*	
Non-CHP baseline, total	**23**	**2**	**1**	**1**	**20**
Total heat output	**63**	**21**		**42**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**46**	**17**		**28**	
Individual	*29*	*17*	*1*	*1*	*10*
District heating	*16*			*16*	
Non-CHP baseline, total	**17**	**4**	**0**	**0**	**13**
Total heat output	**63**	**21**		**42**	


Galloway Forest Park
Northumberland National Park
Carlisle
Lake District National Park
Yorkshire Dales National Park
N
0 10 20 40 Kilometers
Contains OS data © Crown Copyright and database right 2015
Heat Density Map
MWh/km 2
North West England
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Department of Energy & Climate Change

England: Yorkshire and the Humber

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**55**	**25**	**2**	**3**	**25**
Heat only gas/oil boilers	44	16	2	3	24
Electric heating	4	3	0	0	1
Gas CHP and backup boilers	6	6	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	49	22	2	3	22
	Biomass CHP + gas boilers	15	13	0	1	
	Biomass boilers	24	13	1	2	9
	Air to water heat pumps	29		1	3	24
	Ground source heat pumps	26		1	3	22
	Solar thermal + gas boilers	31		1	3	26
	Solar thermal + biomass boilers	14		1	2	11
District heating	Gas CHP + gas boilers	26		26		
	Biomass CHP + gas boilers	26		26		
	Biomass boiler	26		26		
	Ground source heat pumps	26		26		
	Water source heat pumps	14		14		
	Power station heat	6		6		
	Waste incinerator heat	0		0		
	Industrial waste heat	0		0		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

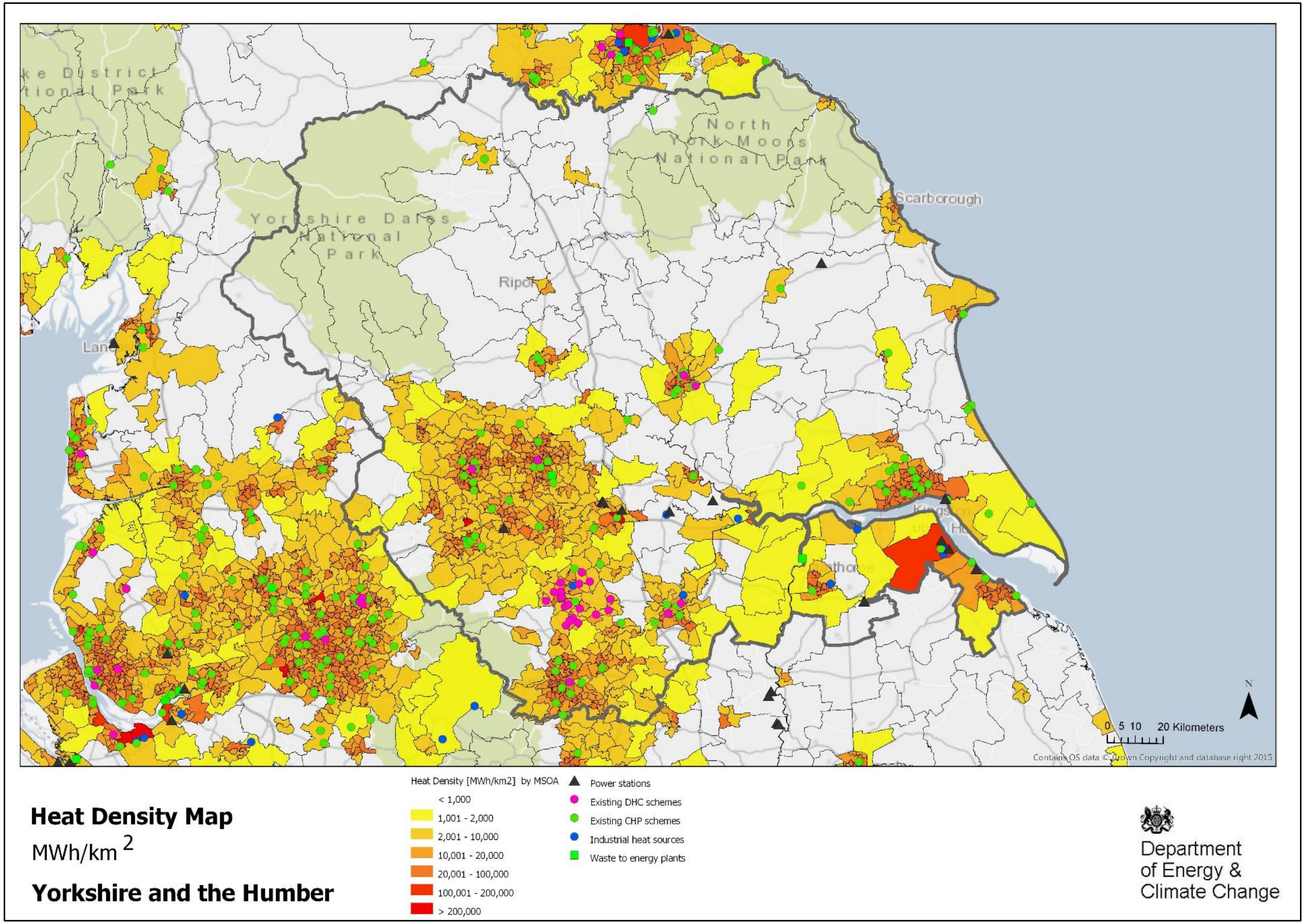
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**23**	**20**		**3**	
Individual	*22*	*20*	*0*	*1*	*0*
District heating	*2*			*2*	
Non-CHP baseline, total	**31**	**5**	**1**	**1**	**25**
Total heat output	**55**	**25**		**30**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**36**	**22**		**15**	
Individual	*23*	*22*	*0*	*0*	*1*
District heating	*14*			*14*	
Non-CHP baseline, total	**19**	**4**	**0**	**0**	**15**
Total heat output	**56**	**25**		**31**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**42**	**21**		**21**	
Individual	*31*	*21*	*0*	*1*	*9*
District heating	*11*			*11*	
Non-CHP baseline, total	**13**	**4**	**0**	**0**	**9**
Total heat output	**56**	**25**		**30**	


North York Moors National Park
Yorkshire Dales National Park
Scarborough
N
0 5 10 20 Kilometers
Contains OS data © Crown Copyright and database right 2015
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Heat Density Map
MWh/km 2
Yorkshire and the Humber
Department of Energy & Climate Change

England: East Midlands

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**28**	**5**	**1**	**1**	**21**
Heat only gas/oil boilers	25	3	1	1	20
Electric heating	2	1	0	0	1
Gas CHP and backup boilers	1	0	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	24	4	1	1	18
	Biomass CHP + gas boilers	2	1	0	0	
	Biomass boilers	12	2	1	1	9
	Air to water heat pumps	23		1	1	20
	Ground source heat pumps	21		1	1	18
	Solar thermal + gas boilers	25		1	1	23
	Solar thermal + biomass boilers	13		1	1	12
District heating	Gas CHP + gas boilers	17		17		
	Biomass CHP + gas boilers	17		17		
	Biomass boiler	17		17		
	Ground source heat pumps	17		17		
	Water source heat pumps	9		9		
	Power station heat	4		4		
	Waste incinerator heat					
	Industrial waste heat	0		0		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

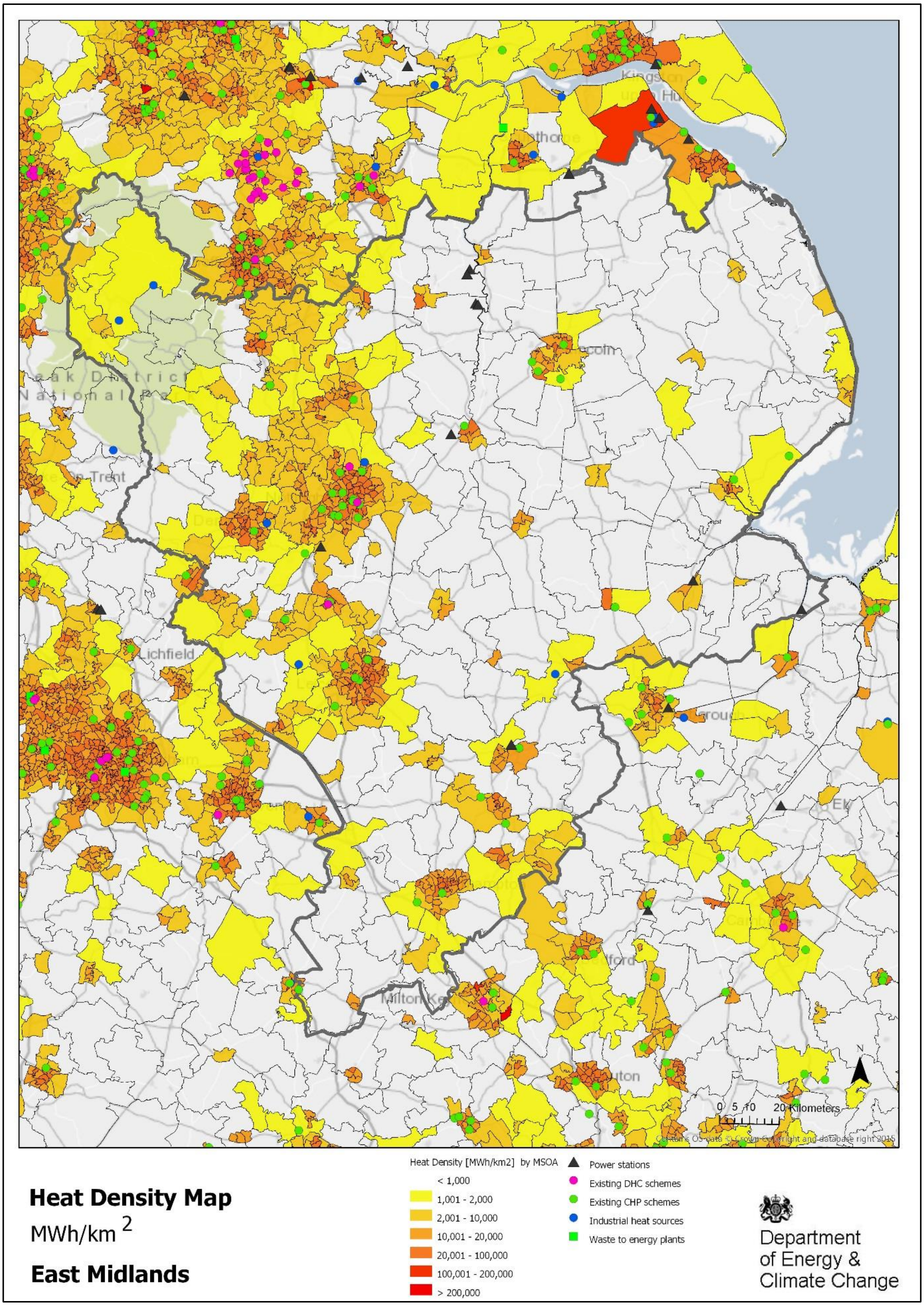
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**4**	**2**	**1**		
Individual	*4*	*2*	*0*	*1*	*0*
District heating	*0*		*0*		
Non-CHP baseline, total	**24**	**2**	**1**	**1**	**20**
Total heat output	**28**	**5**	**23**		

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**14**	**3**	**11**		
Individual	*5*	*3*	*0*	*0*	*1*
District heating	*10*		*10*		
Non-CHP baseline, total	**14**	**1**	**0**	**0**	**12**
Total heat output	**29**	**5**	**24**		

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**19**	**3**	**16**		
Individual	*11*	*3*	*0*	*1*	*8*
District heating	*8*		*8*		
Non-CHP baseline, total	**10**	**2**	**0**	**0**	**7**
Total heat output	**29**	**5**	**24**		


Heat Density Map
MWh/km 2
East Midlands
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Department of Energy & Climate Change
Lichfield
0 5 10 20 Kilometers
N

England: West Midlands

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**31**	**3**	**1**	**2**	**25**
Heat only gas/oil boilers	29	3	1	2	23
Electric heating	2	0	0	0	2
Gas CHP and backup boilers	0	0	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	28	3	1	2	21
	Biomass CHP + gas boilers	1	1	0	0	
	Biomass boilers	7	1	0	0	6
	Air to water heat pumps	28		1	2	25
	Ground source heat pumps	24		1	2	21
	Solar thermal + gas boilers	28		1	2	24
	Solar thermal + biomass boilers	9		0	0	8
District heating	Gas CHP + gas boilers	22		22		
	Biomass CHP + gas boilers	22		22		
	Biomass boiler	22		22		
	Ground source heat pumps	22		22		
	Water source heat pumps	10		10		
	Power station heat	2		2		
	Waste incinerator heat	0		0		
	Industrial waste heat	0		0		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

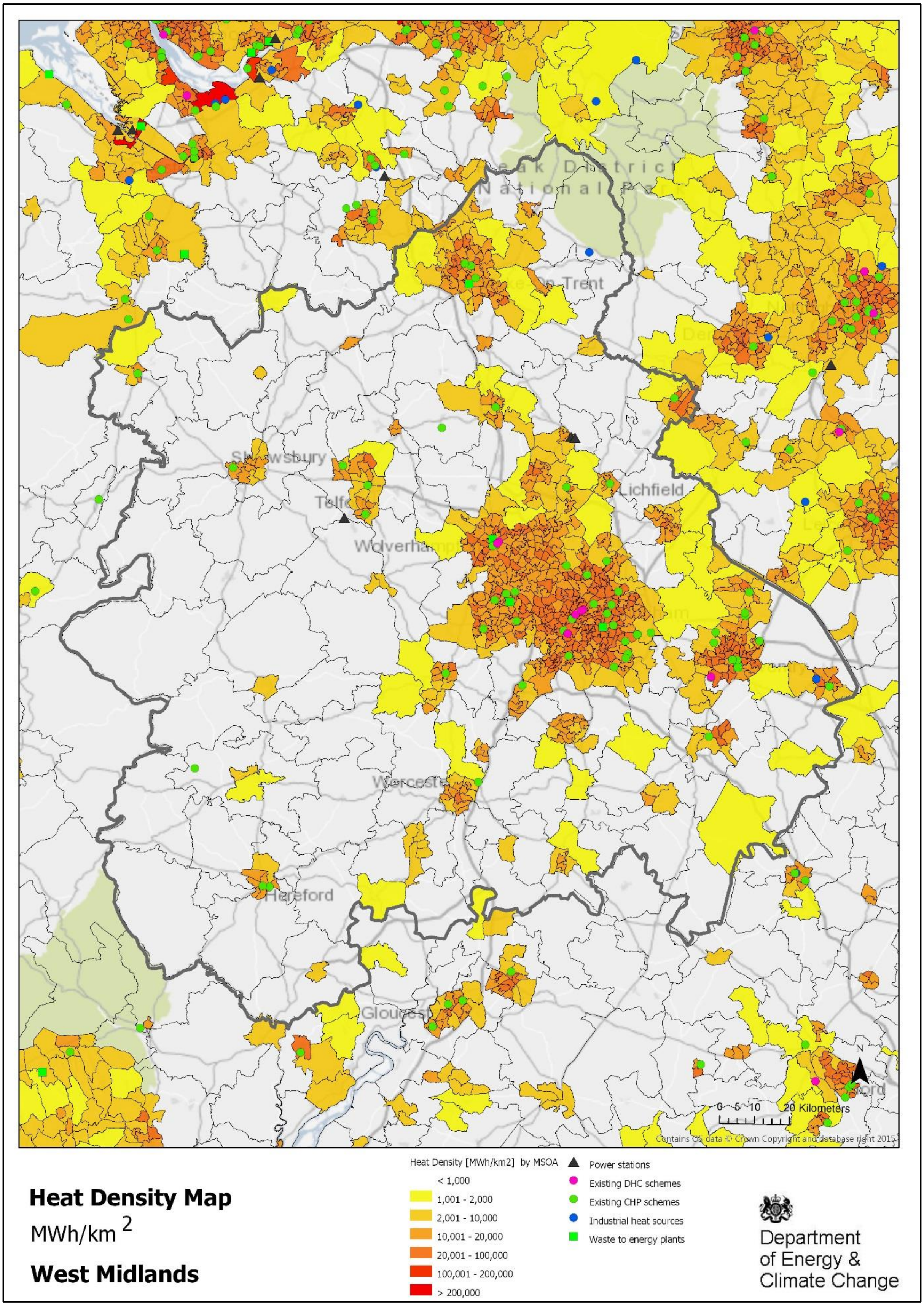
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**3**	**1**	**2**		
Individual	*3*	*1*	*0*	*1*	*0*
District heating	*0*		*0*		
Non-CHP baseline, total	**28**	**2**	**1**	**1**	**24**
Total heat output	**31**	**3**	**28**		

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**18**	**2**	**16**		
Individual	*3*	*2*	*0*	*0*	*0*
District heating	*15*		*15*		
Non-CHP baseline, total	**15**	**1**	**0**	**0**	**14**
Total heat output	**33**	**3**	**30**		

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**22**	**2**	**20**		
Individual	*11*	*2*	*0*	*1*	*8*
District heating	*12*		*12*		
Non-CHP baseline, total	**11**	**1**	**0**	**0**	**9**
Total heat output	**33**	**3**	**29**		


Lichfield
Hereford
N
0 5 10 20 Kilometers
Contains OS data © Crown Copyright and database right 2015
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Heat Density Map
MWh/km 2
West Midlands
Department of Energy & Climate Change

England: East of England

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**37**	**7**	**1**	**2**	**27**
Heat only gas/oil boilers	33	5	1	2	25
Electric heating	3	1	0	0	3
Gas CHP and backup boilers	1	1	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	31	7	1	2	21
	Biomass CHP + gas boilers	5	4	0	0	
	Biomass boilers	23	5	1	1	17
	Air to water heat pumps	30		1	2	27
	Ground source heat pumps	24		1	2	21
	Solar thermal + gas boilers	31		1	2	28
	Solar thermal + biomass boilers	24		1	1	22
District heating	Gas CHP + gas boilers	21		21		
	Biomass CHP + gas boilers	21		21		
	Biomass boiler	21		21		
	Ground source heat pumps	21		21		
	Water source heat pumps	10		10		
	Power station heat	5		5		
	Waste incinerator heat	0		0		
	Industrial waste heat	0		0		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

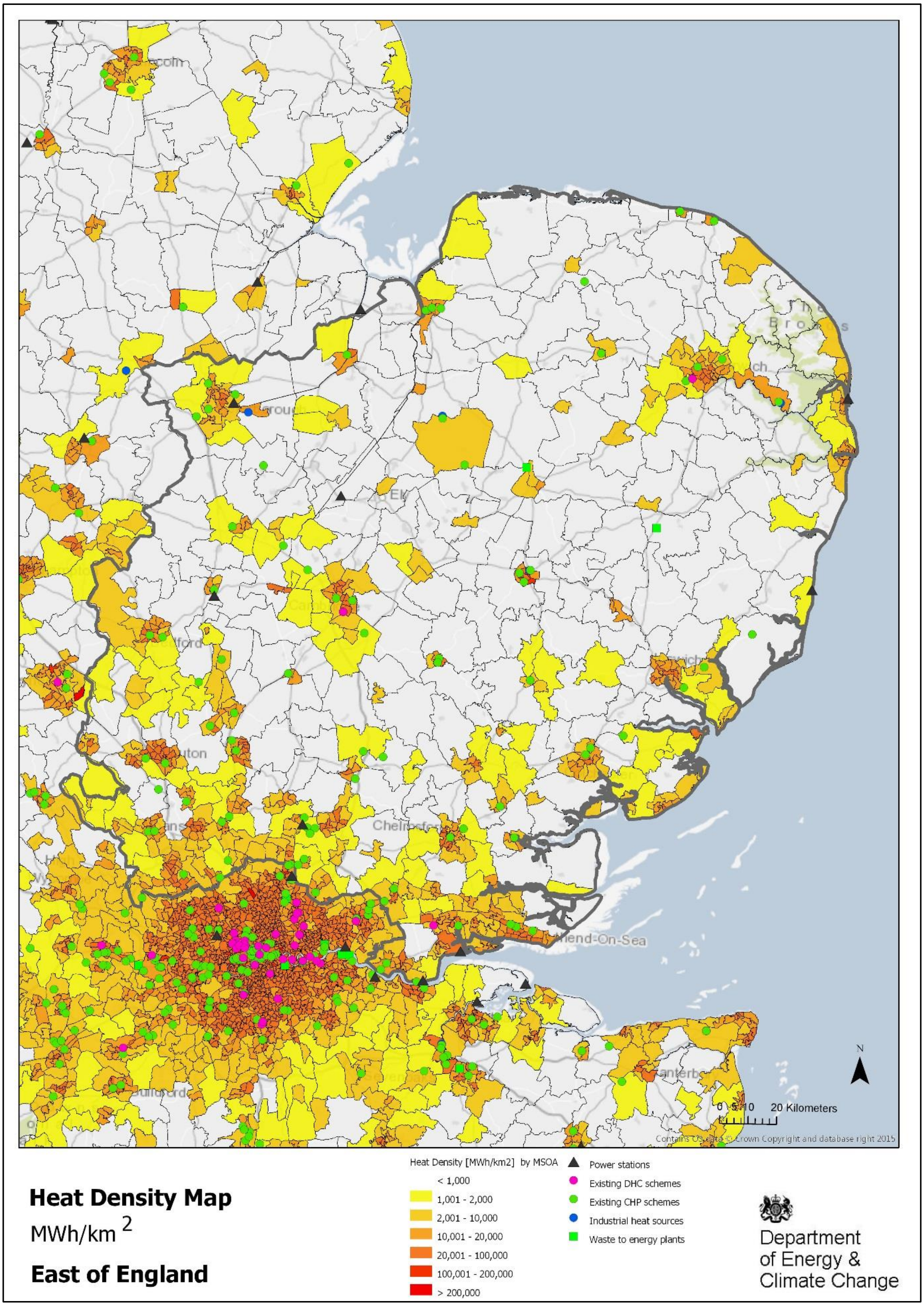
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**7**	**6**	**1**		
Individual	*6*	*6*	*0*	*0*	*0*
District heating	*0*		*0*		
Non-CHP baseline, total	**31**	**1**	**1**	**1**	**27**
Total heat output	**37**	**7**	**30**		

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**24**	**6**	**18**		
Individual	*9*	*6*	*0*	*0*	*2*
District heating	*15*		*15*		
Non-CHP baseline, total	**15**	**1**	**0**	**0**	**13**
Total heat output	**39**	**7**	**32**		

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**30**	**6**	**24**		
Individual	*17*	*6*	*0*	*1*	*10*
District heating	*13*		*13*		
Non-CHP baseline, total	**9**	**1**	**0**	**0**	**8**
Total heat output	**39**	**7**	**32**		


Heat Density Map
MWh/km 2
East of England
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Department of Energy & Climate Change
0 5 10 20 Kilometers
N

England: London

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**42**	**2**	**2**	**3**	**34**
Heat only gas/oil boilers	37	1	2	2	31
Electric heating	4	0	0	0	3
Gas CHP and backup boilers	1	0	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	38	2	2	3	31
	Biomass CHP + gas boilers	0	0	0	0	
	Biomass boilers	0	0	0	0	0
	Air to water heat pumps	39		2	2	34
	Ground source heat pumps	26		2	2	21
	Solar thermal + gas boilers	25		2	2	21
	Solar thermal + biomass boilers	0		0	0	0
District heating	Gas CHP + gas boilers	42				42
	Biomass CHP + gas boilers	42				42
	Biomass boiler	42				42
	Ground source heat pumps	42				42
	Water source heat pumps	15				15
	Power station heat	5				5
	Waste incinerator heat	1				1
	Industrial waste heat	0				0

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

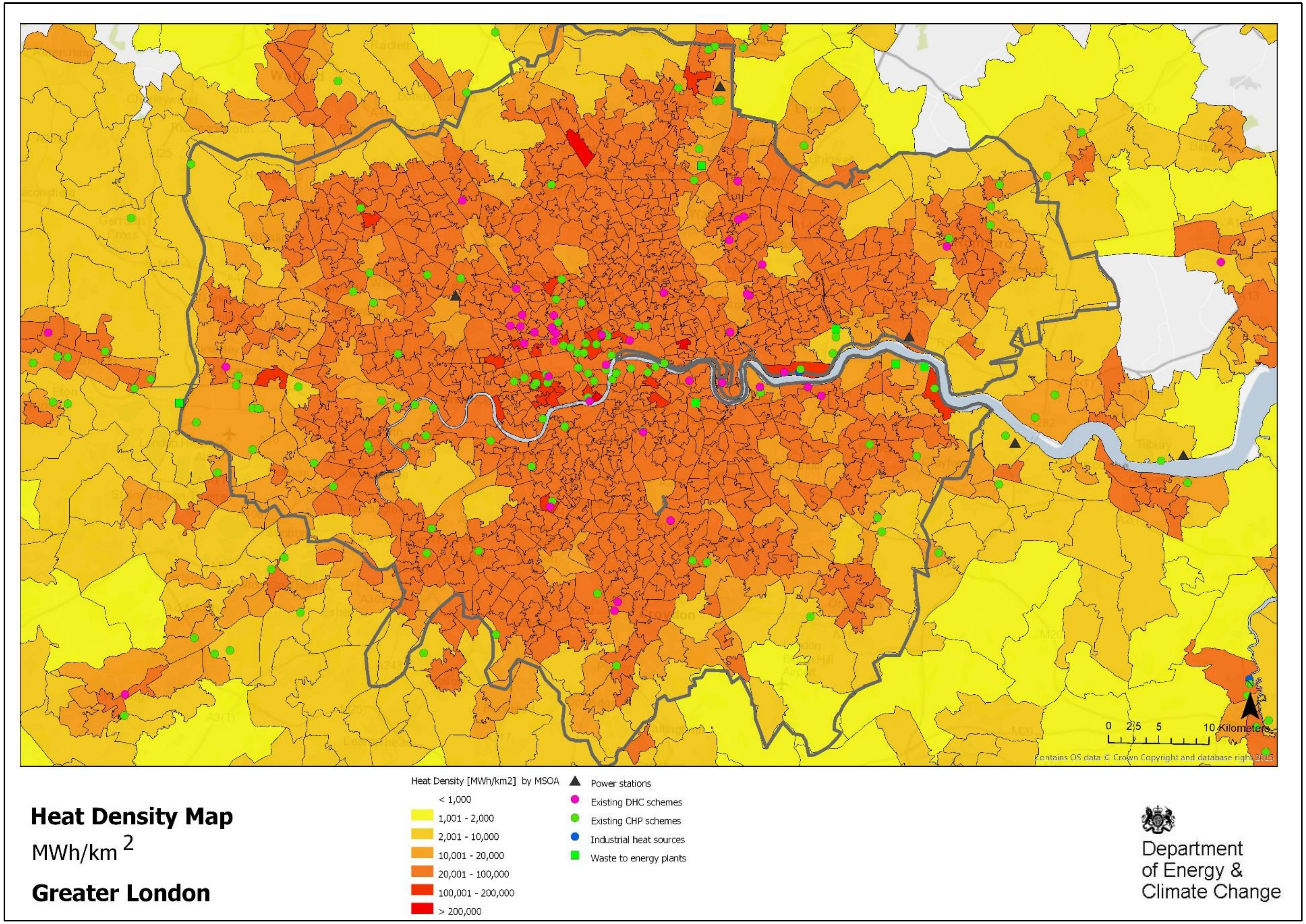
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**4**	**1**		**3**	
Individual	*3*	*1*	*0*	*1*	*0*
District heating	*1*			*1*	
Non-CHP baseline, total	**38**	**1**	**1**	**1**	**34**
Total heat output	**42**	**2**		**39**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**40**	**2**		**38**	
Individual	*2*	*2*	*0*	*0*	*0*
District heating	*38*			*38*	
Non-CHP baseline, total	**6**	**0**	**0**	**0**	**5**
Total heat output	**46**	**2**		**44**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**43**	**1**		**42**	
Individual	*4*	*1*	*0*	*0*	*2*
District heating	*39*			*39*	
Non-CHP baseline, total	**4**	**1**	**0**	**0**	**2**
Total heat output	**46**	**2**		**44**	



0 2.5 5 10 Kilometers
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Heat Density Map
MWh/km 2
Greater London
Department
of Energy &
Climate Change

England: South East

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**59**	**13**	**3**	**2**	**40**
Heat only gas/oil boilers	51	9	3	2	37
Electric heating	5	1	0	0	3
Gas CHP and backup boilers	3	3	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	50	12	3	2	33
	Biomass CHP + gas boilers	6	5	0	1	
	Biomass boilers	29	6	1	1	21
	Air to water heat pumps	45		3	2	40
	Ground source heat pumps	36		3	2	31
	Solar thermal + gas boilers	46		3	2	41
	Solar thermal + biomass boilers	29		1	1	27
District heating	Gas CHP + gas boilers	30		30		
	Biomass CHP + gas boilers	30		30		
	Biomass boiler	30		30		
	Ground source heat pumps	30		30		
	Water source heat pumps	16		16		
	Power station heat	5		5		
	Waste incinerator heat	1		1		
	Industrial waste heat	1		1		

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

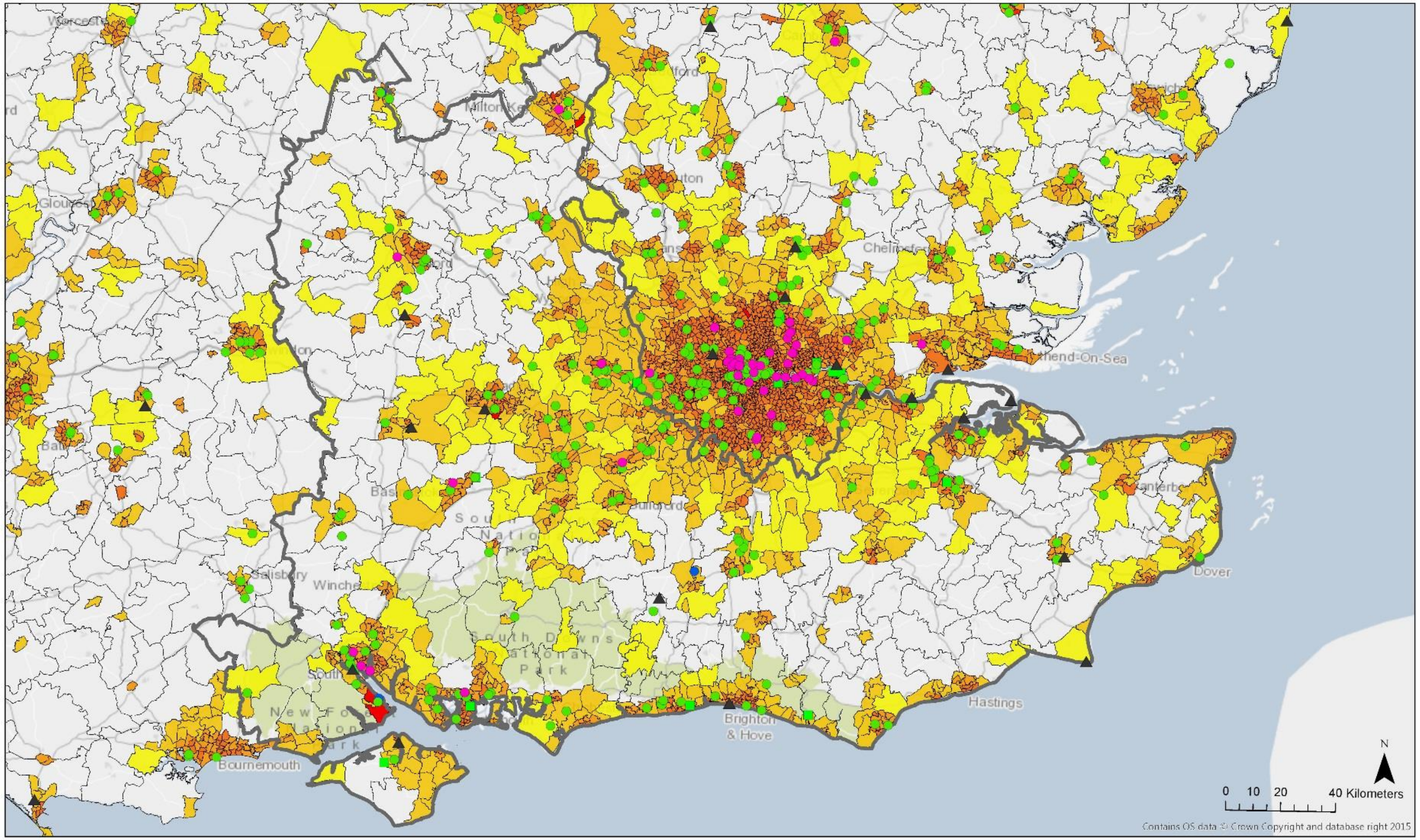
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**14**	**11**		**3**	
Individual	*12*	*11*	*1*	*1*	*0*
District heating	*2*			*2*	
Non-CHP baseline, total	**45**	**2**	**1**	**1**	**40**
Total heat output	**59**	**13**		**46**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**34**	**11**		**23**	
Individual	*13*	*11*	*0*	*0*	*1*
District heating	*21*			*21*	
Non-CHP baseline, total	**27**	**2**	**1**	**0**	**24**
Total heat output	**61**	**13**		**48**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**45**	**11**		**34**	
Individual	*28*	*11*	*1*	*1*	*15*
District heating	*17*			*17*	
Non-CHP baseline, total	**16**	**2**	**0**	**0**	**13**
Total heat output	**61**	**13**		**48**	



Heat Density [MWh/km2] by MSOA
- < 1,000
- 1,001 - 2,000
- 2,001 - 10,000
- 10,001 - 20,000
- 20,001 - 100,000
- 100,001 - 200,000
- > 200,000

- Power stations
- Existing DHC schemes
- Existing CHP schemes
- Industrial heat sources
- Waste to energy plants

Heat Density Map

MWh/km ^{2}

South East England

Department
of Energy &
Climate Change

England: South West

Baseline expressed as TWh of heat output pa.

Heating solutions	Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Baseline, total	**28**	**2**	**1**	**2**	**22**
Heat only gas/oil boilers	24	2	1	2	20
Electric heating	3	1	0	0	2
Gas CHP and backup boilers	0	0	0	0	

Technical Potentials for high-efficiency solutions, TWh of heat output pa.

High-efficiency heating solutions		Total TWh	Industry (incl. agriculture TWh	Commercial Services TWh	Public Services TWh	Residential TWh
Individual	Gas CHP + gas boilers	21	2	1	2	17
	Biomass CHP + gas boilers	2	1	0	1	
	Biomass boilers	18	1	1	1	15
	Air to water heat pumps	25		1	2	22
	Ground source heat pumps	19		1	2	17
	Solar thermal + gas boilers	25		1	2	23
	Solar thermal + biomass boilers	21		1	1	19
District heating	Gas CHP + gas boilers	20		20		
	Biomass CHP + gas boilers	20		20		
	Biomass boiler	20		20		
	Ground source heat pumps	20		20		
	Water source heat pumps	13		13		
	Power station heat	3		3		
	Waste incinerator heat					
	Industrial waste heat					

Cost-effective potential of high-efficiency solutions under the full finance costs scenario, TWh of heat output pa

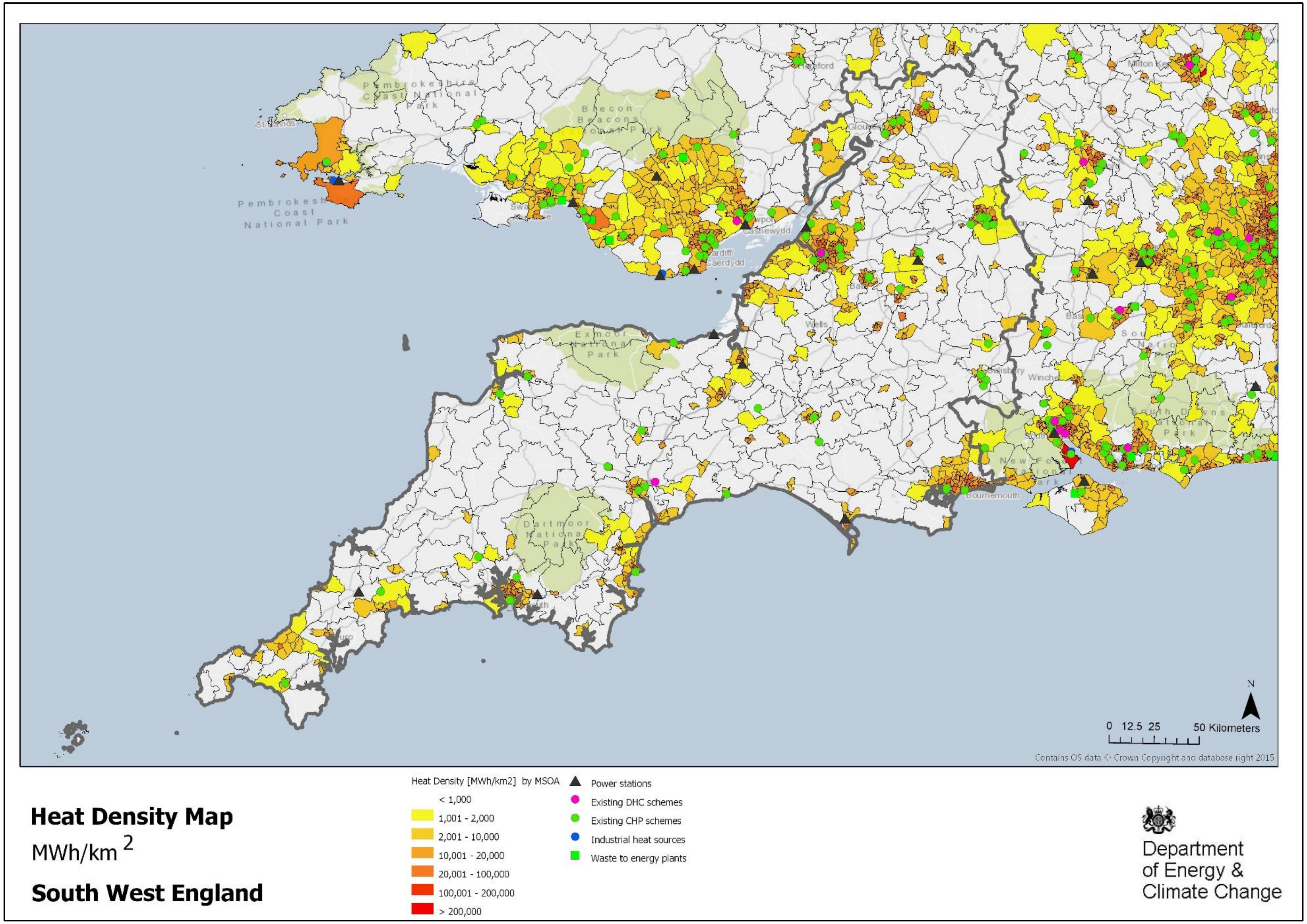
Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**3**	**1**		**2**	
Individual	*3*	*1*	*0*	*1*	*1*
District heating	*0*			*0*	
Non-CHP baseline, total	**25**	**1**	**1**	**1**	**21**
Total heat output	**27**	**2**		**25**	

Cost-effective potential of high-efficiency solutions under the zero finance costs scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**16**	**2**		**15**	
Individual	*5*	*2*	*0*	*0*	*3*
District heating	*12*			*12*	
Non-CHP baseline, total	**13**	**1**	**0**	**0**	**11**
Total heat output	**29**	**2**		**26**	

Cost-effective potential of high-efficiency solutions under the extreme carbon price scenario, TWh of heat output pa.

Heating solutions	Total TWh pa	Industry (incl. agriculture) TWh pa	Commercial Services TWh pa	Public Services TWh pa	Residential TWh pa
High efficiency, total	**16**	**2**		**15**	
Individual	*9*	*2*	*0*	*1*	*7*
District heating	*7*			*7*	
Non-CHP baseline, total	**12**	**1**	**0**	**0**	**11**
Total heat output	**28**	**2**		**26**	



Pembrokeshire Coast National Park
Brecon Beacons National Park
Exmoor National Park
Dartmoor National Park
New Forest National Park
South Downs National Park
Bournemouth
0 12.5 25 50 Kilometers
N
Contains OS data © Crown Copyright and database right 2015
Heat Density [MWh/km2] by MSOA
< 1,000
1,001 - 2,000
2,001 - 10,000
10,001 - 20,000
20,001 - 100,000
100,001 - 200,000
> 200,000
Power stations
Existing DHC schemes
Existing CHP schemes
Industrial heat sources
Waste to energy plants
Heat Density Map
MWh/km 2
South West England
Department of Energy & Climate Change

Appendix 2: Methodology

Overview of the methodology

In preparing the UK's National Comprehensive Assessment (NCA) for high-efficiency CHP and efficient district heating and cooling, the project has involved determining the spatial distribution of the heating and cooling loads (annual consumptions) of all sectors of the UK economy and what these might be in 2025. In addition, a Cost Benefit Analysis (CBA) has been carried out whereby technical and cost effective potential to satisfy these loads by energy efficient supply options has been determined, including high-efficiency CHP, micro-CHP and efficient district heating and cooling.

The assessment has been undertaken in stages as follows:

- Extraction of data from various input data sources to determine the "current" (taken as 2012 after a review of data availability) annual heat and cooling consumptions by geographic area across the UK.
- Projection of those consumptions to 2025.
- Generation of spatially defined data layers for the mapping of heat and cooling densities. Also of the locations of existing CHP plants, district heating schemes, power stations, waste incinerators and industrial sources of waste heat.
- Assessment of the technical potential for high-efficiency heat supply solutions in two categories:
    - Individual solutions: for satisfying the heat consumption of an individual building or site.
    - District heating (DH) solutions: for satisfying the aggregate heat consumption of a defined geographic area.

  Unfortunately the poor spatial resolution of cooling consumption data and the elective nature of comfort cooling in the UK has meant that it was not possible to model district cooling solutions with sufficient confidence in the validity of the results.
- Assessment of the socially cost-effective potential of the solutions via cost-benefit analysis. The assessment has been undertaken in line with the guidance set out in the HM Treasury Green Book and the supplementary guidance on valuing carbon emissions avoided, energy savings and air quality improvements.
- The cost-benefit analysis has employed a social time preference rate of 3.5% to discount cash flows to present values, with cash-flow lines for:
    - capital costs;
    - fixed and variable operating costs;
    - long-run variable costs (LRVC) of energy;
    - air quality damage costs;
    - costs of carbon; and
    - cost of finance.
- The cost-benefit analysis does not include the impact of any current or future policies to support specific technologies or fuels.

Development of the bespoke model

The assessment process has principally been realised via a bespoke model constructed in Microsoft Access and implemented in the form of a series of Microsoft SQL queries, with the data used being stored in a series of linked Access databases.

In the main, the necessary pre-processing of data was carried out in Excel and GIS software prior to entry into the model with some carried out within the Access model itself.

The CBA model was thus built in a Microsoft Access database and primarily implemented in the form of a series of Microsoft SQL queries that extracted data from the relevant data sources, generated the heat map, modelled a range of potential high-efficiency technology options and identified the most cost effective solutions.

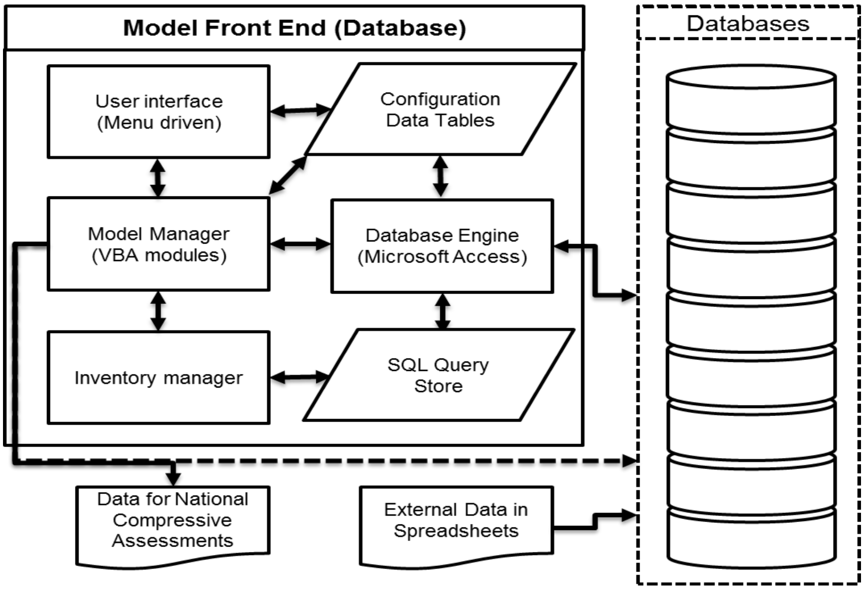
Some parts of the initial modelling process were completed using GIS software (for example, the collation of building floor area data) and the results imported into the CBA model. The heat density data needed to plot the UK heat maps was exported from the CBA model and overlaid on UK base layer maps using the GIS software.

In summary the model includes:

- A simple menu driven interface with an interface to the model manager's data set filtering routines and search engine. These facilities were configured to enable users to review the heat map data or results for a specific area (OA, LSOA, MSOA, Built Up Area and their equivalents in Scotland and Northern Ireland).
- An inventory manager to define the sequence in which queries are run and store copies of queries along with QA documentation on their design and operation. The inventory manager also implements part of the version control system by retaining copies of the previous version of queries, so they can be recalled if required.
- The routines that automatically link the front-end to the back-end databases that contain the data needed to model different regions and areas of the UK, and the results of modelling work. The UK was divided into 52 separate modelling "zones" (made up of combinations of NUTS1 to NUTS3 areas) to keep the size of datasets being processed within the limits of Access.

A schematic overview of the NCA model is provided below.

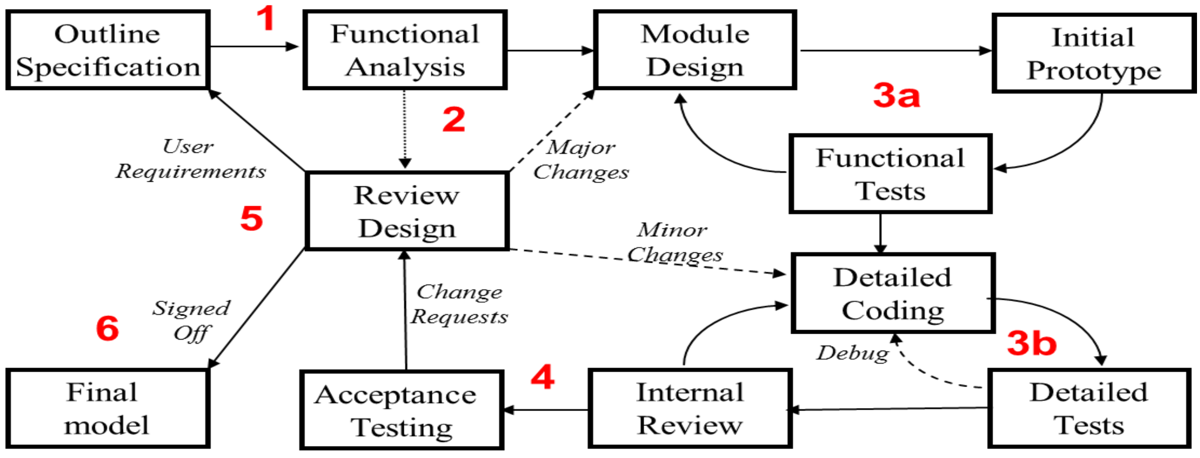
Overview of the NCA model



A rapid prototyping method was used to customise the model manager and to develop the SQL queries used. This involved testing the model on a subset of the heat map data, before scaling it up to operate on the full data set.

An overview of the design lifecycle is shown below.

Overview of the model development lifecycle



The model development methodology consisted of six main steps:

1. An outline specification subjected to functional analysis (the model's design was divided into modules that were built and tested individually, then integrated together and tested).
2. The proposed model design was reviewed and any additional requirements added to the specification.
3. A two-stage design process for each module:
   a) An initial prototype built and tested to verify that the design concepts worked.
   b) A detailed version developed and subjected to more rigorous testing.
4. A three-stage design review process during which the operation of:
   a) Each module was reviewed and verified by a team member other than the designer.
   b) The overall model reviewed and checked against the design specification.
   c) The finalised model is acceptance tested by a prospective user.
5. A final design review is carried out when any changes requests are discussed and agreed.
6. The final model is accepted and signed-off once the specification had been satisfied.

Modelling approach

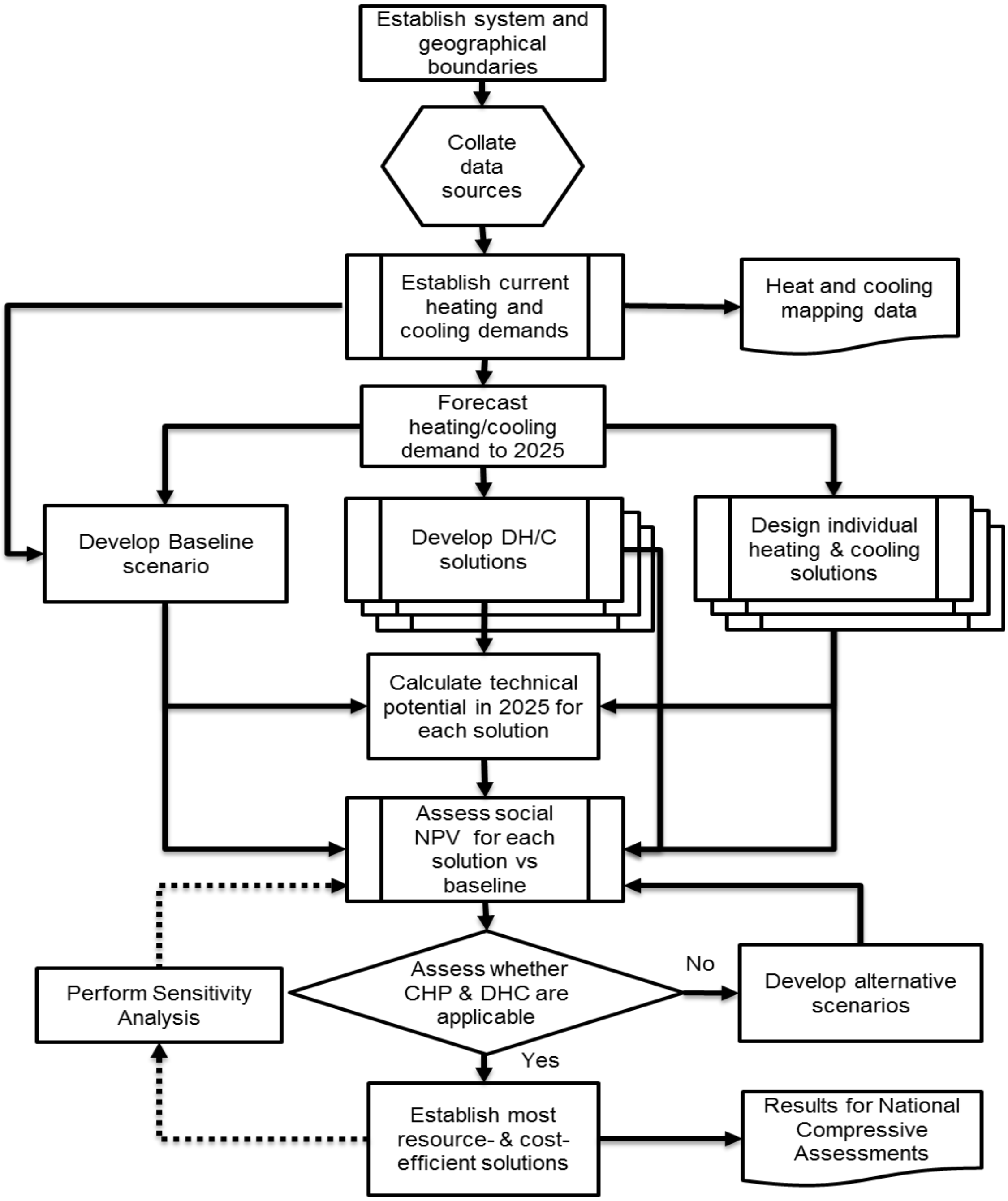
In utilising the model described above, the following steps were carried out:

- Establish system and geographical boundaries and collate data sources
- Establish current heating and cooling consumptions
- Compile heating and cooling mapping data
- Projection of heating and cooling consumptions to 2025
- Develop baseline scenario
- Design individual heating & cooling solutions (NB: cooling solutions not developed as consumption data too unreliable)
- Develop district heating & cooling solutions (NB: cooling solutions not developed as consumption data too unreliable)
- Calculate technical potential for each solution
- Assess the social NPV for each solution vs baseline
- Assess whether DHC and/or CHP are applicable in each area or not.
- Develop alternative scenarios for areas where DHC schemes and/or individual CHP solutions are not applicable

- Establish most resource- and cost-efficient solutions
- Perform sensitivity analysis
- Compile results for the Comprehensive Assessment

This sequence is illustrated schematically below followed by short descriptors summarising the key steps.

Overview of the modelling process



Assessment

Establish System and Geographical Boundaries and Collate Data Sources

Spatial definitions

For the purposes of the heat mapping and the modelling of heat supply solutions, standard UK statistical geographies have been employed. These are described on the Office for National Statistics website, http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/glossary/index.html, with the key terms used outlined in this report's glossary.

Heat consumption has been determined spatially for each individual property in the UK. Unique Property Reference Numbers (UPRNs) have been used to identify individual properties and these have been linked to data on fuel use, heating and cooling consumption and standard UK statistical geographies, specifically Output Areas (OAs), Lower Layer Super Output Areas (LSOAs), Middle Layer Super Output Areas (MSOAs) and Built-up Areas (BUAs) or their devolved administration equivalents as shown in the table below.

Statistical geographies employed

Statistical geography	Territory	UK total
Census 2011 Output Areas (OAs)	Great Britain	232,296
Small Areas (SAs)	Northern Ireland	
Lower Layer Super Output Areas (LSOAs)	England & Wales	42,625
Data Zones (DZs)	Scotland	
Super Output Areas (SOAs)	Northern Ireland	
Middle Layer Super Output Areas (MSOAs)	England & Wales	9,602
Intermediate Zones (IZs)	Scotland	
Wards	Northern Ireland	
Built-up Areas (BUAs)	England & Wales	6,458
Scottish Settlements (SSs)	Scotland	
Northern Ireland Settlements (NIS)	Northern Ireland	

Each MSOA (or equivalent) comprises a number of LSOAs, each of which in turn comprise a number of OAs. Built-up areas and settlements are separate from this structure.

Boundaries

The overall system boundaries are Scotland and the rest of the UK but the modelling has been carried out for multiple sub-regions within.

The capital costs of district energy are made up of different components including

- The primary pipe network of pipes from the central plant room, which typically run along streets.
- Building specific components: the branch connection pipes and heat exchangers or hydraulic boards that connect individual buildings to the primary pipework, and heat metering.

The capital cost of the primary pipe network is thus significant and is approximately in proportion to the network length, which is assumed to equate with the total length of streets. Whilst the linear heat density (heat consumption / street length) is the metric generally used in assessing DH viability, it requires a detailed analysis of length of main pipework branches connecting the primary networks to individual properties and the number of building connections for individual streets / neighbourhoods. It has thus been assumed that DHC schemes will be confined to built-up areas/settlements.

The geographies at which individual DH schemes are modelled determines the sub-regional boundaries at which the social cost effectiveness of individual heating/cooling and DHC solutions are compared. These results are then aggregated and reported at larger sub-regional levels (e.g. LAU 1 Local

Authorities and UK NUTS 1 regions), which is necessary due to the high number of potential DH schemes.

Built-up areas were created by ONS as part of the 2011 Census outputs by examining 50m x 50m areas and designating each as built or not built based on 2011 census data and a number of other assumptions, see link:

http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/built-up-areas---built-up-area-sub-divisions/index.html

Settlements comprise adjacent 50m x 50m OS Grid squares that are individually identified as being built up with a total area of at least 20 hectares and with settlements within 200m of each other linked. Some very small settlements are omitted but the vast majority of buildings in the UK are captured. Digital boundaries are drawn around the settlements identified.

DH schemes are not typically designed to serve entire settlements from the outset but could be designed to do so under an ambitious scenario of DH development. However, even in a very ambitious scenario, this would seem unlikely to happen in the foreseeable future for a large city such as Greater London (divided essentially by the Thames into North and South London) due to sheer size.

The largest DH Schemes in the UK are currently the Sheffield and Nottingham Schemes, each of which spans parts of approximately four different MSOAs but do not feed the entire heat load of any MSOA and are nowhere near the size of the Sheffield and Nottingham Built-up Areas or Local Authority areas. Another large scheme, the Pimlico DH Scheme, spans approximately half of one MSOA and a small part of another to the west. All these schemes have been developed over several decades. On this basis it has been assumed that the most realistically ambitions individual DH developments would not be larger than an MSOA in scale in the UK before 2025.

In theory, the full technical potential would encompass a DHC scheme in every settlement serving every building. However, rural and suburban areas with very low population densities are very unlikely to achieve a positive social NPV compared to the baseline. For this reason, the EED Annex Viii clause 1(c) (i) allows member states to exclude geographical areas with a plot ratio[51] <0.3 from the analysis. Plot ratio is defined as the ratio of building floor area to land area in a given geography.

Plot ratio

Using plot ratio to define the limits of DH viability avoids the need to calculate street lengths for ever area. **A minimum plot ratio threshold of 0.3 was used to define the technical potential for DH.**

To calculate plot ratio, the total land area for each BUA/SS/NIS in each MSOA/IZ, LSOA/DZ, were obtained from ONS and NRS publications and the location, footprint area and (where available) height of each building in GB was extracted from the OS Master Map's topography layer using GIS software. Data on unbuilt on "open spaces" within each urban area was also extracted from OS Master Map.

To calculate building floor area, the numbers of storeys in each building were estimated by assuming an average storey height of 3 metres and then rounding the number of storeys to the nearest integer, and then multiplying the result by the footprint area to calculate total gross floor area of each building. Where height data was unavailable for particular buildings, it was assumed these buildings had two storeys.

For Northern Ireland, areas of Northern Ireland Settlements, Wards, SOAs and SAs were obtained separately from NISRA publications and data on building floor areas gathered by surveyors was obtained from DFPNI's Land and Property Services. This dataset did not cover the entire building stock in Northern Ireland, so average floor areas for similar types or classes of buildings in the local authority area were used to fill the gaps. No data was available on "open spaces" in urban areas.

The data on building floor areas and land areas was collated at Output Area (or Small Area) level and then aggregated up to LSOA and MSOA level. The open space area was deduced from the land area of the BUA prior to calculation of the plot ratio for the area covered by each potential DH scheme.

The MSOA/LSOA subdivisions assumed large urban schemes in order to limit DH schemes to a reasonable size.

[51] The plot ratio for a geographical area is the total gross floor area of inhabited buildings in the area divided by the land area and is a good indicator of DH viability

Plot ratio was calculated at two geographical scales (MSOAs and LSOAs) and, in order to account for the range of possible optimum solutions, DH schemes were considered at the following scales:-

i) Separate networks in each MSOA within built-up areas with a plot ratio ≥0.3

ii) Separate networks in each LSOA within built-up areas with a plot ratio ≥0.3

iii) Individual networks for groups of contiguous LSOAs within MSOAs within built up areas with plot ratios ≥0.3

The model calculated the total social NPV for each MSOA within each built-up area for the first three of these four options and automatically selected the DH Scheme option with the highest social NPV.

DH schemes fed by waste heat sources were aligned with the same geographical areas but inter-connected according to capacity of closest waste heat source, and included in the DH Scheme selection options alongside DH scheme options base around river and sea water source heat pumps.

Alternatives to DHC: Geographical boundaries for individual site solutions

For each site, individual heating and cooling solutions were developed for the baseline case and each high-efficiency technology included in the analysis. These high-efficiency solutions were used to identify the most socially cost effective alternative where connection to a DHC scheme was not cost effective.

The high-efficiency CHP solution for each individual site (or building type) with the best NPV was then identified, and compared with the NPVs of the baseline solution (and alternative non-CHP solutions).

Establish current heating and cooling consumptions

Calculating the annual heating and cooling consumption for each individual demand point (building, installation or existing DHC Scheme), involved combining data on:

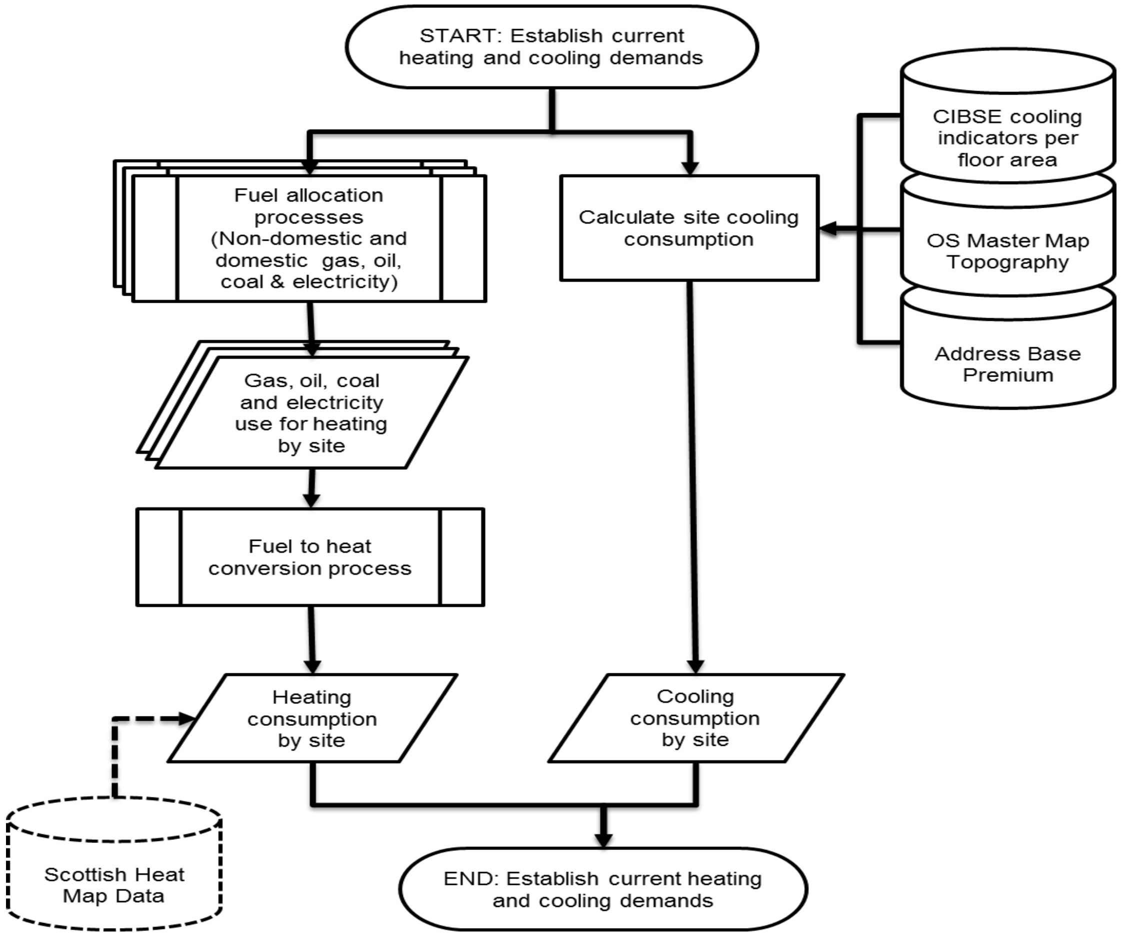
- Fuel consumption at various spatial resolutions from individual site to national levels.
- Heating and cooling energy use.
- Employment statistics
- Building co-ordinates

The figure below provides an overview of the process that has been used to calculate heat and cooling consumption. Within this process, there are a number of separate sub-processes that make use of different types of data that is available for domestic and non-domestic buildings, and different fuel types.

The approach used in determining annual heat consumption where there were individual demand points, CHP sites and DH schemes **with site specific energy data** is outlined as follows:

- There are approximately 3,000 sites/DH schemes with individual energy consumption data. Heating consumption was calculated based on site specific heating and fuel data.
- The proportion of non CHP fuel used to generate heat was estimated based on the national average proportions of fuel used for space heating, hot water and low temperature process heat in the appropriate sector as reported in ECUK data.
- Non CHP heating fuel consumption was converted to heat consumption assuming a heating efficiency of 100% for electricity 75% for other fuels.
- For sites with CHP, CHP fuel consumption was deducted from the total, converted to heat consumption as above and added to measured CHP heat consumption to calculate the total heat consumed by the site.

Overview of process used to establish heating and cooling consumptions



For the **remaining sites with no site-specific energy data**, national and sub-national domestic and non-domestic fuel use was apportioned to output areas for domestic and to postcodes for non-domestic using 2011 census data and IDBR sector employment statistics respectively. The fuel use was converted to heat demand and allocated to individual properties in each output area or postcode by relative floor area. This approach is outlined in more detail as follows:

- The fuel consumption for each of the demand points with individual energy data was subtracted from the ECUK fuel total in the appropriate sector to estimate the remaining fuel consumed by the large number of non-domestic buildings where individual energy consumption data was not available. This was combined with IDBR employment data to produce a first estimate of the consumption of heating fuels in each sector in each postcode.
- DECC's National Housing Model was combined with 2011 census data to produce a first estimate of heating fuels consumed by each house type in each output area.
- The consumption of heating fuels in individual buildings was then estimated using data on gross floor area within each postcode and sector for non-domestic buildings and within each census area for domestic buildings.
- Gas and electricity consumptions were calibrated using sub-national statistics.
- Finally the proportion of fuel used for heating and conversion to heat consumption were done in the same as for demand points with site specific energy data except in the case of dwellings with electric heating where economy 7 sub national electricity consumption was assumed to equate to heat consumption.

UPRNs were used to identify individual properties and these were linked to data on fuel use, heating and cooling consumption, sources of heating and cooling, coordinates, OS areas (OA, LSOA, and MSOA).

Where datasets with site specific information do not include UPRNs, then address and post code data, or map coordinates were used to identify the specific building or site to which the data belongs.

Where fuel use data was only available in aggregated form and not to specific properties, then national and sub-national domestic and non-domestic fuel use was apportioned to output areas / postcodes respectively using 2011 census data and IDBR sector employment statistics. The fuel was covered to heat consumption and allocated to individual properties in each output area / postcode on the basis of floor area.

Compile heating and cooling mapping data

A database containing the following information was compiled to enable heating and cooling consumption maps for the UK to be produced (also showing sources of heat, e.g. CHP):

- Unique property reference number (if available) and co-ordinates for each site
- Description of site type (i.e. building or installation, DHC plant room)
- Annual heating and cooling consumption / consumption for each site (in kWh/year)
- Sector (i.e. industry, commercial, domestic), and either sub-sector or dwelling type.
- Data used to allocate heating and cooling consumption (actual, employment etc.)

And for sites with heating consumption > 20GWh/year:

- Existing heating fuel/type
- Heat grade in terms of hot water/steam/low temperature, dry heat.

In addition, potential heating supply points were identified:

- Unique reference number and co-ordinates for each site
- Description of heat source (i.e. high grade industrial waste heat, electricity generation station using more than 20GWh/year, waste to energy plants, CHP plant and DHC schemes).
- Annual heating supply capacity (in kWh/year)

For Scotland, the data used by the model is based on the Scotland heat map.

Project heating and cooling consumptions to 2025

In order to project the heating and cooling consumptions to 2025, DECC's 2014 Updated Energy & Emissions Projections (UEP) of energy consumption was used to project forward the breakdown of heating and cooling consumptions from the base year of 2012.

These projections provided UK national projections of the fuel consumption from 2015 to 2035 in:

- Agriculture
- Iron & Steel
- Other industrial sectors
- Commercial services sector
- Public sector
- Residential (domestic)

In the domestic sector, the projections of heating and cooling consumptions also took account of:

- DCLG's projections of the growth in UK household numbers
- Historical rates for the demolition of dwellings

Develop the baseline scenario

The baseline that was used is a simplified representation of current and anticipated replacement heating technologies that would be employed between 2015 and 2025 under a business as usual scenario.

According to the 2011 census, gas, electric, oil and solid fuel central heating systems comprise the majority of domestic heating fuel/system types in the UK (there are three other categories: non central heating; 'other' fuel; and multiple fuel, however, in the absence of better information, it has been assumed these fell within one of the main four central heating types). Other data sources such as

RESTATS[52] give high level splits of renewable technology installed by UK country in terms of fuel/energy consumption. As these sources, do not provide the type of breakdown data needed to model the distribution of domestic renewable heating systems across the UK, it has been assumed that all domestic properties are fitted with one of four main central heating types for which detailed census data was available.

For NAEI point loads, the heat consumption is assumed to be provided either by a single boiler or a CHP scheme with a top-up boiler. The majority fuel used on site and in CHP schemes is used in the model.

Other non-domestic UPRNs are assumed to have a single boiler fired on the majority fuel in the postcode, or use electric heating where electricity is the majority source of heat within the postcode.

The baseline scenario assumes that these heating technologies will be replaced with the same type of heating technologies but that the replacement plant will have higher efficiencies that existing plant.

Thus for constructing the baseline it was assumed that existing domestic boilers would be replaced by gas or oil boilers, depending on gas availability, and that non-domestic boilers would always be replaced by gas boilers and existing electric heating would be replaced with electric heating. For new dwellings, the proportion of electric heating systems would be the same as the current split.

For existing sites with CHP and for existing district heating, the fuel split is known but to avoid modelling multiple fuels/heating plant types, all were assumed to have a single boiler and up to one CHP with one fuel (the majority existing fuel) and that existing CHP and boilers would be replaced with gas CHP and boilers of the same capacity.

In summary it has been assumed that:

- Heat-only gas and oil boilers are replaced with improved efficiency gas boilers or, for dwellings only, with improved efficiency oil boilers where gas is not available.
- Electric heating is retained.
- Existing gas CHP systems, including associated top-up boilers are replaced with like sized gas CHP systems.
- Existing district heating schemes are retained and treated as individual demand points whose central plant would be replaced by gas heat-only boilers or CHP with top-up boilers.
- New dwellings are fitted with improved efficiency gas boilers (or oil boilers where gas is not available) or electric heating on a pro-rata basis.
- Existing district heating networks will be retained and these were treated as individual demand points (as consumed at the existing plantroom i.e. including network losses) served by gas heat only boilers or CHP with top-up boilers.

Design individual heating & cooling solutions

In modelling the solutions, these have to be sized appropriately for each individual heat load so that capital, operational and external costs can be calculated from appropriate cost and efficiency parameters.

It has been assumed that biomass boilers and heat pumps would be sized to provide the peak heat demand and supply all of the annual heat consumption. The same has been assumed for 1kWe micro-CHP, which is usually designed as a direct replacement for domestic boilers without the need for a separate top-up boiler. However, solar thermal panels and CHP (with the 1kWe exception) are not normally sized to provide the peak demand as this is usually uneconomic. It has therefore been assumed that these would be sized to provide a proportion of the annual heat consumption with top-up heat-only boilers providing the balance.

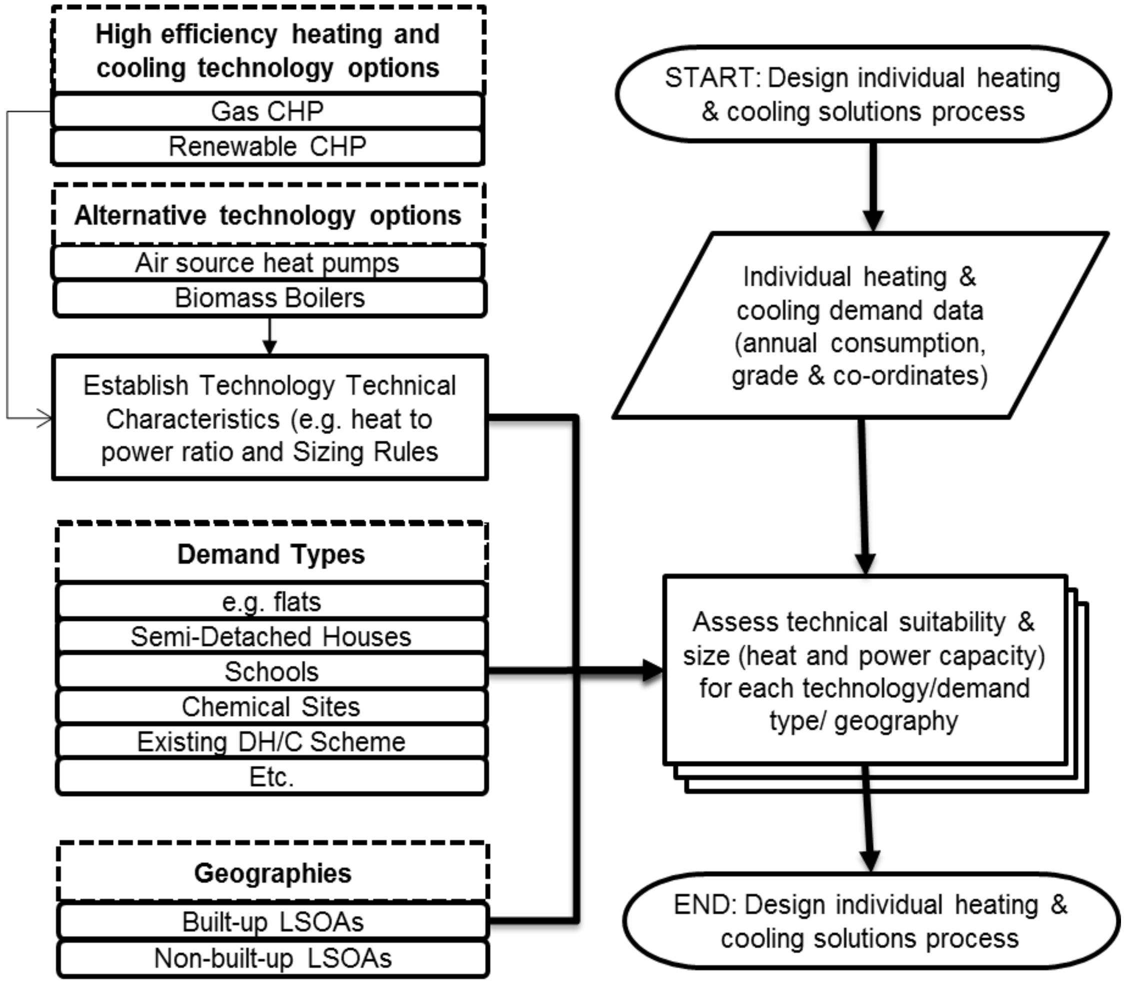
Four main types of solution were considered as part of the assessment: gas CHP, renewable CHP (i.e. biomass CHP) and alternative solutions (air source heat pumps and biomass boilers).

The model also designs baseline solutions for the existing heating and cooling systems in order to assess the costs and benefits of their replacement.

[52] https://www.gov.uk/government/collections/renewables-statistics

The figure below outlines the process used to design the individual heating and cooling solutions deployed in each area.

Overview of the design individual heating and cooling solutions process



A key step in this process is the sizing of individual solutions to match the heat load. This was done using a set of design rules for each technology to determine the thermal capacity (and for CHP, electrical capacity) of the solution best suited to the heat load. These design rules were stored in a look up table that includes a description of the solution (e.g. gas engine CHP) and the parameters that define technical performance (e.g. efficiency), and capital and operating cost.

The look up tables for CHP technologies were based on those used in Ricardo- Energy & Environment's CHP Bottom Up model, whilst the lookup tables for other technologies were based on the typical design values used in previous assessments including for example: *The UK Supply Curve for Renewable Heat* (NERA & AEA, 2009) and the *Review of technical information on renewable heat technologies* (AEA, 2011).

The lookup tables were included in the inputs and assumptions log that accompany the model, together with details of the references used to derive the technical and financial parameters.

Summary tables of the DH and individual, high efficiency solutions assessed are given below.

Summary of high efficiency district heating solutions assessed

District heating solution type	Sub-type	Assumptions/comments
Gas CHP and gas top-up boilers	Up to 4 MWe gas engine with gas top-up boilers	Thermal stores included Assumed that CHP provides a certain proportion of annual heat demand depending on CHP size
	4-40 MWe open cycle gas turbine (OCGT) with gas top-up boilers	
	>40 MWe combined cycle gas turbine (CCGT) with gas top-up boilers	
Biomass CHP and gas top-up boilers	0.2–2.5 MWe organic Rankine cycle with gas top-up boilers	Thermal stores included Assumed that CHP provides a certain proportion of annual heat demand depending on CHP size
	>2.5MWe steam turbine with gas top-up boilers	
Biomass boilers		Thermal stores included Sized for peak heat demand.
Ground source heat pumps		Thermal stores included Sized for peak heat demand.
Water source heat pumps		Thermal stores included Sized for peak heat demand England only
Recoverable heat sources	Conventional power stations	Replace condensing steam turbine with extraction steam turbine. Thermal stores included
	Energy from waste plants	
	Industrial waste heat sources	Thermal stores included

Summary of individual high efficiency solutions assessed

Individual solution type	Sub-type	Assumptions/comments
Gas CHP and gas top-up boilers as necessary	1 kWe (electric capacity) gas micro-CHP with no top-up boiler	Integral boiler and Stirling engine. Sized for peak heat demand.
	1-4,000 kWe gas engine with gas top-up boilers	Only the CHP component is reported as high-efficiency heating potential. Assumed that CHP provides a certain proportion of annual heat demand depending on CHP size
	4-40 MWe open cycle gas turbine (OCGT) with gas top-up boilers	
	>40 MWe combined cycle gas turbine (CCGT) with gas top-up boilers	
Biomass CHP and gas top-up boilers	0.2–2.5 MWe organic Rankine cycle with gas top-up boilers	200 kWe smallest biomass CHP available. Assumed that CHP provides a certain proportion of annual heat demand depending on CHP size
	>2.5MWe steam turbine with gas top-up boilers	
Biomass boilers		Sized for peak heat demand.
Air source heat pumps		Air to water. Sized for peak heat demand.
Ground source heat pumps		Sized for peak heat demand.
Solar thermal panels with gas/oil boiler top-up boilers		Only the solar thermal component is reported as high-efficiency heating potential. 50% of domestic hot water supplied by solar thermal.
Solar thermal panels with biomass boiler top-up boilers		Both components are reported as high-efficiency heating potential. 50% of domestic hot water supplied by solar thermal.

Develop district heating & Cooling (DHC) solutions

Unlike individual solutions where the size is defined by the individual building or site's heat demand, district heating schemes can range in coverage with a wide number of possible configurations.

Each DH scheme is considered as comprising of a low or medium temperature[53] hot water system serving every non-industrial building within a geographical area using every road/street to connect the buildings. Industrial buildings are excluded as DH consumers as they generally require steam networks and anticipating the different options for industrial groupings and pipe routings would be very data intensive.

As individual industrial demands are relatively large, the social and economic benefit economies of scale associated with linking them are generally more limited and many suitable industrial areas are already served by such networks. Industry as a supplier of waste heat to DH is included.

The figure below outlines the process that the model used to develop DH solutions for each area of the heat map, and to evaluate the likely size of central heating plant. A number of different design options were considered during the modelling process including the geographical area covered by the solution, the grade of heat being distributed and the availability of waste heat. A similar modelling process was developed for district cooling solutions, but not implemented due to data quality/availability issues.

The relative merits of six different types of purpose built central heating and cooling plant, based around the use of gas or biomass CHP, gas or biomass boilers (without CHP) and ground or water source heat pumps and heat recovery from three waste sources (industry, thermal power only stations and existing CHP) needed to be considered.

The model designed a solution for each technically possible combination of options in each area, and the costs and benefits of each option will be assessed as part of the CBA and the DH solution with the solution with the best NPV adopted.

The total street length in each area was used to estimate the capital cost of building a DH energy distribution network, as it was not possible to undertake detailed design work on specific schemes.

The primary network is normally a tree structure consisting of a main pipe sized to carry the total network load and branch mains which carry numbers of loads decreasing with each level in the tree ending with the smallest pipes at the ends of roads which carry heat for a single building.

The detailed DH design process generates a breakdown of the pipe lengths and sizes needed to build the scheme, and this is used to work out the cost of pipework, installation and distribution losses.

The assumptions used to evaluate costs of DH schemes, included:

- The cost of pipework assumptions from Annex I of the study by Parsons Brinkerhoff (2009)[54].
- On average pipework is sized to carry 50% of the peak load (CCC Study, 2009)[55].
- The cost of connection of individual dwellings from Poyry (2009)[56]
- Recent/current work for DECC on the costs of district heating undertaken by AECOM

These assumptions were triangulated against the results of more recent published work, where possible, to establish the level of uncertainty introduced into the model as a result of their use.

In accounting for existing DH networks, the new DH solutions developed by the model were scaled down to reflect the proportion of the road network in each MSOA served by the existing DH scheme.

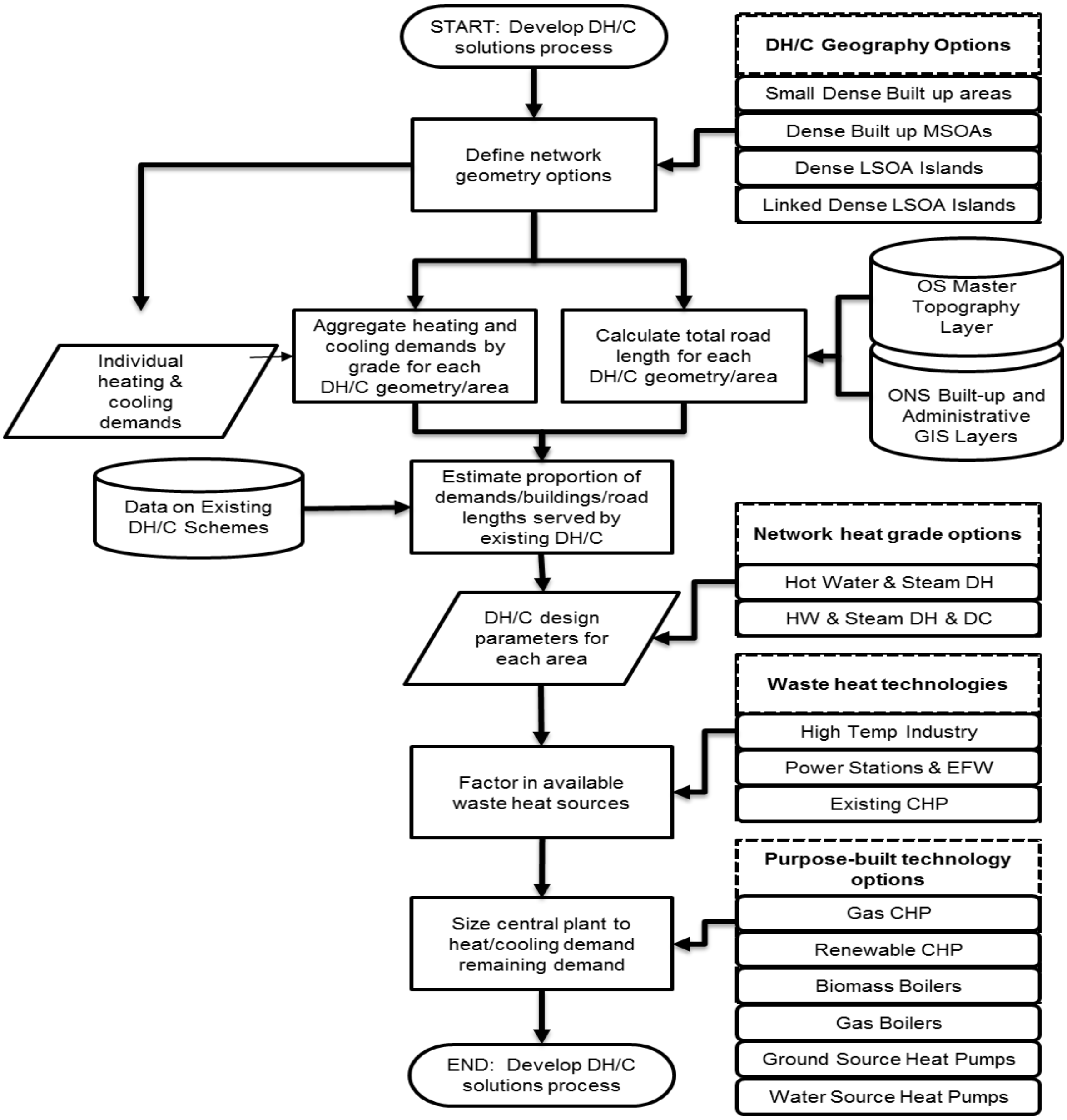
[53] In low temperature DH networks, all parts of the network remain below 100C but in medium temperature DH, water leaves the central plant at slightly above 100°C under pressure to prevent boiling and turning to steam. The latter is used in larger networks.

[54] Heating Supply Options for New Development – An Assessment Method for Designers and Developers, Parsons Brinkerhoff, 2009, Report published by Scottish Government, Directorate of Build Environment.

[55] 2050 options for decarbonising heat in buildings, A report for CCC, Element Energy & AEA, April 2012

[56] The cost and potential of District Heating Networks, A report for DECC, Poyry / Faber Mansell, April 2009.

Overview of the DH solutions development process



Central plant costs were assessed using the same look up tables used for individual technologies, with the following adjustments:

- Different design rules were used to size the central plant. These took into account the diversity in the demand of individual users, which enabled DH to be sized at between 50% and 80% of the size needed to serve a single user with a similar total demand.
- “Back up” heating plant were factored into the costing. Typically these are gas fired boilers that are used to meet demand during maintenance periods and to service peaks in demand that cannot be met by central CHP, which are typically sized to serve part of the peak load.
- Thermal stores were included in the costing, as these are generally used to level out heat demand and to provide a heat sink that enables CHP operation at times of lower demand.
- Central absorption chillers would also be included in the costing where a scheme provides cooling. A separate cooling distribution network would be included in DHC scheme costings.

In all cases, single rather than hybrid heat sources were assumed for heat networks (although gas fired back-up boilers were included in capex, as these are currently the lowest cost option).

District heating geometry options

As previously noted, the EED Annex VIII clause 1(c) (i) allows Member States to exclude areas with a plot ratio <0.3 from the heat map, this assessment has assumed that each DH scheme is constrained to areas with a plot ratio of at least 0.3.

This high level approach restricts the possibilities to a manageable level but should still take into account the range of possible optimum DH solutions. In order to allow a degree of optimisation, the social resource and cost effectiveness of installing DH schemes with the following geographical coverage options have been assessed[57]:

- Separate networks for each MSOA within BUAs, where the geographical area covered by the network has a plot ratio ≥0.3
- Separate networks for each LSOA within BUAs, where the geographical area covered by the network has a plot ratio ≥0.3
- Individual networks for groups of contiguous LSOAs within MSOAs within BUAs, where the geographical area covered by the network has a plot ratio ≥0.3

The plot ratio calculations were undertaken following the removal of open spaces such as parks.

The model calculated the total social NPV for each MSOA within each built-up area for these 4 options and selected the option with the highest social NPV out of the first three options. The fourth option was used for analysis and comparison only.

The approach taken by region is outlined as follows:

For England & Wales:

i) One DH network serving each MSOA within each Built-Up Area (BUA)[58]. MSOAs with a plot ratio less than 0.3 were excluded.

ii) One DH network serving each LSOA within each BUA. LSOAs with a plot ratio less than 0.3 were excluded.

iii) As ii) but with one DH network serving each contiguous group of LSOAs within each MSOA.

MSOAs with plot ratio ≥0.3 shaded orange.

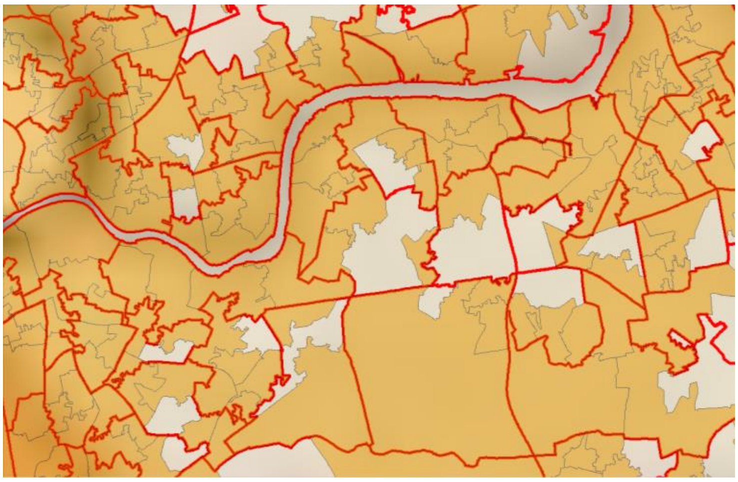
MSOA boundaries are red and MSOAs with a plot ratio ≥0.3 are shaded orange. In geometry approach i), it was assumed that a DH scheme is developed in each MSOA with plot ratio ≥0.3

[57] Most of these geographical boundaries are based on the Output Areas defined by the Office of National Statistics (ONS) for the analysis and mapping of Census data. OAs are the lowest geographical level at which census estimates are provided. Output areas were introduced in Scotland at the 1981 Census and in all the countries of the UK at the 2001 Census. http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/output-area--oas-/index.html. In England and Wales, Output Areas (OAs) are combined to form Lower Layer Super Output Areas (LSOAs) and Middle Layer Super Output Areas (MSOAs). In Northern Ireland, only a single level of Super Output Areas (SOAs) is defined. In Scotland, Output Areas (OAs) are combined to form Data Zones (DZs) and Intermediate geography Zones (IZs).

[58] Built-up areas were created by ONS as part of the 2011 Census outputs by examining 50m x 50m areas and designating each as built or not built based on 2011 census data and a number of other assumptions.

http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/built-up-areas---built-up-area-sub-divisions/index.html

<u>LSOAs with plot ratio ≥ 0.3.shaded orange</u>



MSOA boundaries are red and LSOA boundaries are grey. LSOAs with a plot ratio ≥0.3 are shaded orange.

All approaches were calculated and the one resulting in the highest NPV selected.

For Scotland and Northern Ireland the closest equivalents to the England and Wales geographies have been used.

For Scotland:

i) One DH network serving each Intermediate Zone (IZ) within each Scottish Settlement[59] (SS). IZs with a plot ratio less than 0.3 were excluded.

ii) One DH network serving each Data Zone (DZ) within each SS. DZs with a plot ratio less than 0.3 were excluded.

iii) As ii) but with one DH network serving each contiguous group of DZs within each IZ.

For Northern Ireland:

i) One DH network serving each electoral ward within each Northern Ireland Settlement (NIS). Electoral wards with a plot ratio less than 0.3 were excluded.

ii) One DH network serving each Super Output Area (SOA) within each NIS. SOAs with a plot ratio less than 0.3 were excluded.

iii) As ii) but with one DH network serving each contiguous group of SOAs within each electoral ward.

In summary:

- Overall system boundaries are Scotland and the rest of the UK
- Modelling carried out for multiple sub-regions (MSOA/IZ/Ward; LSOA/DZ/SOA; and LSOA/DZ/SOA clusters within BUAs/SSs/NISs): the social cost effectiveness of individual heating/cooling and DHC solutions so compared.
- Results are aggregated and reported at larger sub-regional levels (e.g. LAU 1 Local Authorities and UK NUTS 1 regions) which is necessary due to the high number of potential DH schemes.
- In Scotland, modelling is based on IZ, DZ and Scottish Settlements rather than MSOA, LSOA and BUA.
- In Northern Ireland, modelling is based on Ward, SOA and NI Settlements rather than MSOA, LSOA and BUA.

Calculate technical potential in 2025 for each solution

[59] In 2001, NRS defined c. 650 'settlements' based on the density of addresses indicated by postcodes. See: http://www.nrscotland.gov.uk/statistics-and-data/geography/related-publications/scottish-settlements-urban-and-rural-areas-in-scotland/introduction.

The technical potentials in 2025 were based on the results of the design of individual and DH solutions processes, and assumed that all solutions that meet the minimum design criteria for a particular case are technically feasible.

The technical potential that would be realised under the baseline scenario was deducted to identify the additional scope for CHP and DH beyond that expected to be realised under current policies.

In addition to the size of annual heating and cooling consumption, the type of site (DH scheme, non-domestic sector or dwelling type) and the existing heating system and fuel type affect the technical potential for each solution. Whilst it was not practical (or possible) to establish site type and heating type/fuel for each of the individual 29 million demands, it was possible to calculate the technical potential for site groupings (segments) with the same site type and heating fuel in a geographical area based on the average heating and cooling consumption per site in the segment as outlined below.

Residential Segmentation

Whilst the 2011 census gives dwelling counts in each output area split by dwelling type and by heating type/fuel, it is not possible to deduce heating type/fuel for individual dwellings. Thus for modelling purposes (and to make the volume of data more manageable), the dwellings were placed into one of 16 representative categories (segments) according to the type of dwelling type and fuel used. The average heating and cooling consumption per dwelling was then calculated for each segment. This enabled the 27 million dwellings to be represented by 2.5 million representative segments with a known average heating and cooling consumption per dwelling, dwelling type and heating fuel. From this the technical and economic potentials could be calculated.

Non-Domestic Segmentation

As there is no spatial data on numbers of non-domestic properties by heating types and fuels similar to the census data, each non-domestic property was assumed to use the majority fuel in each postcode (as derived from ECUK, employment statistics and sub-national energy data). A UEP sector was assigned to each property based on OS Address Base classification. Using these assumptions, it was possible to model each non-domestic property individually.

Screening of small sites

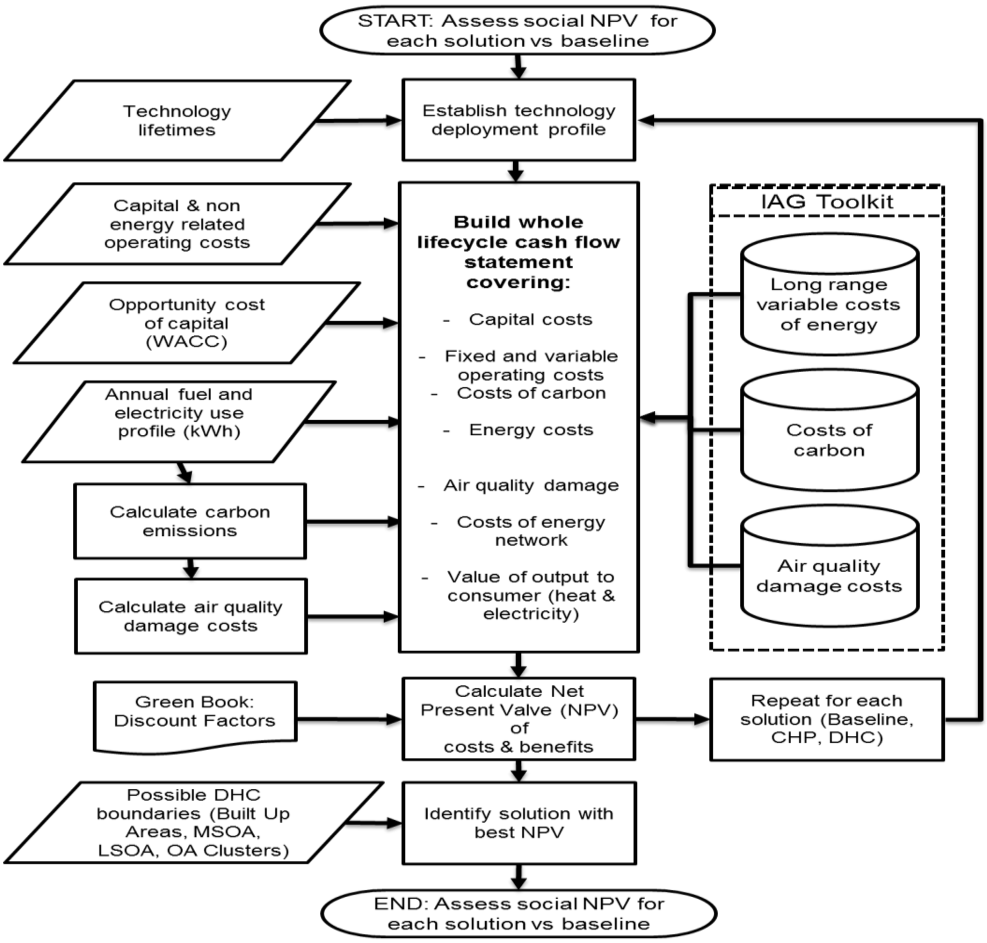
The data volume was reduced from 29 million sites to 4.5 million segments and then 2.9 million. This latter step required applying a lower size limit to screen out sites with calculated heat consumptions below 4MWh/Yr as these would typically not be suited to high-efficiency solutions. Whilst these comprise only about 0.5% of total heat consumption, they make up 34% of the 4.5 million segments, thus doing this reduced the number of segments markedly.

Assess social NPV for each solution vs baseline and whether DHC and/or CHP are applicable in each area or not

For sites with existing CHP, the baseline assumption was that CHP would be replaced with high-efficiency CHP but sized to match the existing power generation capacity of the CHP scheme that qualifies as Good Quality CHP (CHP Qualifying Power Capacity).

During this process, the social NPV of each high-efficiency solution relative to the baseline solution was evaluated (see schematic below that provides an overview of the methodology). This involved building a cash flow statement that spans the lifetime of the heating and cooling technologies involved that was then used to assess which solution was most resource- and cost- effective.

Overview of the assessment of social NPV for each solution vs baseline process



In summary:

- For each MSOA the social Net Present Value (NPV) for all technically suitable district heating options for each of the geometry options was calculated relative to the baseline and the geometry with the highest NPV selected.
- For individual properties in areas not covered by a selected DH option, the NPV of all technically suitable individual CHP options was calculated and the option with the highest NPV selected. For sites with existing CHP, the baseline assumption was that CHP would be replaced with high-efficiency CHP but sized to match the existing Qualifying Power Capacity (QPC).
- For individual properties not assigned to a DH or individual CHP option in the above steps, the NPVs for alternative individual high-efficiency solutions (heat pumps, biomass boilers and solar thermal) were calculated and the option with the highest positive NPV relative to the baseline selected.
- In areas where the Social NPV for all high-efficiency solutions was negative, the baseline solution was assumed to be implemented, so the social NPV was thus zero.

The cash flow statement included separate cash flow lines for:

- Capital costs
- Fixed and variable operating costs
- Energy costs
- The cost of carbon
- Air quality damage costs
- The opportunity cost of capital (cost of finance)

For the reference scenario the variables described in the table below were used. Central IAG air quality damage costs were used in the reference and all other scenarios run.

Cost-benefit analysis: reference (full financing costs) scenario variables

Variable	Values/description
Cost of finance	15% for industry, 10% for non-industrial sectors
Energy prices	IAG 2014[60] long-run variable cost (LRVC) of energy supply, central values
Carbon prices	IAG 2014 carbon prices traded and non-traded, central values
Capex and opex	Best evidence values for each technology

The value of the output to consumers of heat and electricity produced by CHP and DH schemes was evaluated in terms of the cost savings realised by adopting the higher efficiency solutions relative to the baseline solution. The costs of energy (except biomass fuel), carbon and air quality damage were assessed using the lookup tables in the 2014 version of the IAG Toolkit, and the PV of each item in the cash flow calculated using the social time preference discount rates in Table 6.1 of HM Treasury's Green Book (3.5% up to 2045 and 3% between 2046 and 2090).

Avoided Transmission Network Use of System (TUoS) costs as a result of embedded CHP were factored into the cost benefit analysis, as were avoided transmission and distribution network losses.

Of the technologies examined, DHC schemes have the longest design life, between 30 and 50 years (in comparison, a domestic gas fired condensing boiler typically has a design life of 15 to 25 years. In order to address this, the costs and benefits of the different heating and cooling solutions were assessed over a 15 and also a 30 year, period, between 2015 and 2030 (or 2045), with the following assumptions:

- If a high-efficiency solution reaches the end of its life during the assessment period, it is replaced on a "like for like" basis with the same technology and size of heating solution.
- At the end of the assessment period, all operational assets are valued using the straight-line depreciation method across the design life, and this value included in the cash flow.
- Changes in capital cost and efficiency due to technology improvement during the assessment period need not be modelled as the effect on the difference in NPVs is likely to be small.

Due to the data intensity of this process, cash flow statements were prepared for a selection of 6,600 representative solutions and the results of the CBA scaled and applied to solutions of the same type. A scaling method that delivers the same NPV as completing separate cash flows for each building).

For the initial assessment of social cost effectiveness, all technical potential was assumed to be installed at the start of 2015 (except for new buildings which were included in the year constructed). The cost benefit analysis was then repeated with a more realistic deployment profile with high-efficiency solutions being installed in a progressive manner over the period 2015 to 2035 based on the end of life replacement cycles developed for the technologies used in baseline scenario.

Develop alternative scenarios for areas where DHC schemes &/or individual CHP solutions are not applicable

Alternative scenarios were developed for the adoption of other high-efficiency heating and cooling solutions for areas and buildings where DHC and CHP schemes were not applicable or not cost-efficient. Application rules were developed for individual biomass boilers, solar thermal systems with biomass, gas and oil fired backup boilers, air to water heat pumps and ground source heat pumps.

Establish most resource- & cost-efficient solutions

The most resource and cost efficient solution were determined by first examining whether any of the three geometries of DH solutions considered during the assessment had a higher NPV than the baseline solution for a particular area. Where DH solutions offered a higher NPV than the baseline solution, then the model would select the size and type of DH solution that offers the best NPV.

[60] Interdepartmental Analysts' Group on Energy and Climate Change, 2014 Toolkit (https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal)

The model then compares the NPVs of the CHP solutions against the NPV of the baseline solution for each building / site in areas where DH is not cost-effective. Where a CHP solution offers a higher NPV than the baseline, then the model selects the type of CHP solution that offers the best NPV.

Finally the NPVs of alternative individual high-efficiency solutions were compared the baseline solution for each building / site where both DH and CHP are not cost-effective. The solution offering the highest NPV for each of the remaining buildings/sites was then selected. The baseline solution is selected where none of the alternative individual high-efficiency solutions offer a higher NPV than it does.

Perform Sensitivity Analysis

The sensitivity of the results of the CBA to changes in financing costs, capital costs, carbon prices and energy prices was determined by rerunning the model with different assumptions for these factors as shown in the table below.

Cost-benefit analysis: sensitivities

Scenarios	Modification relative to the reference scenario
Zero financing costs	0% for both industry and non-industrial sectors
High cost of finance	20% for industry, 15% for non-industrial sectors
DH modified cost of finance	7.5% for district heating, 15% for industry, 10% for other sectors
Low capex and opex	80% of best evidence values
High capex and opex	120% of best evidence values
Reduced DH network costs	80% of best evidence values for district heating network costs only
Low energy and carbon prices	IAG 2014 low values for both LRVC and carbon
High energy and carbon prices	IAG 2014 high values for both LRVC and carbon
Central retail energy prices	IAG 2014 central values for retail energy prices
Extreme carbon price	£500/tCO_2

Compile data for the Comprehensive Assessment

This step primarily involved aggregating the results of the modelling work to the required level (e.g. LA, MSOA) and exporting the data into an Excel worksheet in a form that allowed the data to be analysed using pivot tables and produce the necessary graphs and tables.

Appendix 3: Key Assumptions

Key cost input parameters

- Discount rate of 3.5% (Social time preference rate)
- Capital costs of plant derived from multiple sources
- Operation and maintenance costs or plant derived from multiple sources
- IAG2014 Table 3: Carbon prices and sensitivities 2008-2100
- IAG2014 Tables 9-13: Long-run variable costs of energy supply
- IAG2014 Table 15: Air quality damage costs
- IAG2014 Table 20: Exchange rate assumptions and GDP deflators

Key spatial and sectoral assumptions

Storey height (or number of storeys where building heights unavailable)
GB Floor to floor height = 3m based on observation so number of storeys = height/3, rounded to nearest whole with a minimum of 1. GB properties in areas with no OS building height information (e.g. Aberdeen) assumed to have two storeys on average.

Properties in multiple occupancy buildings cover an equal share of building floor area
Where a building hosts multiple properties (UPRNs), e.g. tower blocks, the gross floor area of each is an equal share of the total OS building (TOID) floor area

Property classifications
Each OS UPRN classification was assigned to a 2 digit UK SIC (2007) based on the description of the building category in OS Master Map. This is used to identify which UEP sector the property is in.

Minimum floor area and height for occupied buildings
UPRNs with a footprint area <20m^2 or height <2m are not occupied buildings.

Key district heating (DH) techno-economic assumptions

- New DH schemes only serve Built-up Areas (BUAs) with a plot ratio ≥0.3
- New DH is low temperature hot water and does not serve industry
- Primary DH pipes are installed in every street to serve every non industrial property
- Primary DH pipework capex assumed to be same as capex for a network where all pipes are sized to supply 50% of peak demand.
- Branch connections, heat interfaces and meters are sized for each property
- Annual inspection/maintenance costs assumed for heat interfaces
- Current DH schemes are retained rather than being replaced or refurbished.
- Cost of new networks in areas with existing DH equated with the cost of rebuilding a network to serve whole area less the cost of rebuilding existing network.

Average primary network and non-domestic branch pipes sized and costed using the report *'Heating Supply Options for New Development – An Assessment Method for Designers and Developers'*, by Parsons Brinkerhoff, 2009, Appendix I. Sizing is on the basis of a 35°C temperature drop and water velocity of around 3m/s depending on pipe size.

Key heating plant assumptions

- Individual solar thermal, ground source heat pumps and biomass boilers are not suitable for flats.
- Individual solar thermal and ground source heat pumps are not suitable for industry.
- The capital costs of all biomass has been uplifted by 10% to account for additional emissions abatement and oil air quality damage costs employed.

Appendix 4: Data sources

Name and description of data source	Date of data	Domestic/ non-domestic	Geographic coverage	Source (organisation/ programme)
Energy Consumption in the UK (ECUK) 2014 Annual Energy consumption for 2008-2013 split by fuel type by 2 digit SIC Code Sector Classification. 2012 data used in line with sub-national fuel totals	2012	Non-Domestic	UK	DECC
DECC Sub-national Gas & Electricity Statistics for Non Domestic 2012 for England & Wales. Total Non-Domestic Gas and Electricity Consumptions aggregated from supplier sales data/estimated at Middle Layer Super Output Area	2012	Non-Domestic	GB	DECC
DECC Sub-national Gas & Electricity Statistics for Domestic 2012 for England & Wales. Total Non-Domestic Gas and Electricity Consumptions aggregated from supplier sales data/estimated at Lower Level Super Output Area	2012	Domestic	E&W	DECC
DECC Sub-national Gas & Electricity Statistics for Domestic 2012 for Scotland. Total Non-Domestic Gas and Electricity Consumptions aggregated from supplier sales data/estimated at Middle Layer Super Output Area	2012	Domestic	Scotland	DECC
DECC Sub-national Electricity Statistics for 2011 for Northern Ireland. Total Non-Domestic Electricity Consumptions aggregated from supplier sales data/estimated at Middle Layer Super Output Area	2011	Both	NI	DECC
NAEI Gas Data for Northern Ireland 2012 Gas Data from NI Gas suppliers aggregated to LA level by Ricardo Energy & Environment)	2012	Both	NI	NAEI
2011 Census England & Wales Central Heating by Accommodation Type (Includes stock populations for all combinations of gas central heating, oil central heating, electric central heating, solid fuel central heating and household types such us detached, semi-detached, terraced, flats at Lower Level Super Output Area)	2011	Domestic	E&W	Office for National Statistics (ONS)
2011 Census Northern Ireland Central Heating by Accommodation Type (Includes stock populations for all combinations of gas central heating, oil central heating, electric central heating, solid fuel central heating and household types such us detached, semi-detached, terraced, flats at the small area unit level -equivalent to output area	2011	Domestic	NI	NISRA

Name and description of data source	Date of data	Domestic/ non-domestic	Geographic coverage	Source (organisation/ programme)
2011 Census Scotland Central Heating And Accommodation Type Includes stock populations for gas central heating, oil central heating, electric central heating, solid fuel central heating, and separately household types such us detached, semi-detached, terraced, flats at Output Area	2011	Domestic	Scotland	NRS
Output from DECC National Housing Model (NHM) Regional energy consumption estimates per household by house type by fuel type (2010 regional energy consumption estimates per 400 dwellings of a detailed build form (subsets of census dwelling type) and in the presence of central heating were created by DECC on 31st March 2014 from the NHM scenario "GHG_Emissions_Data_Request" version 3. Coal and oil have been calibrated to DUKES; gas and electricity have been calibrated to metered readings	2010	Domestic	GB	DECC
Scotland Heat map data (Data underlying Scotland heat map) Two spreadsheets one with DH details and other with field key, multiple GIS Files with heat demand and supply points and CSV file containing various data including floor areas and calculated heat loads at UPRN level.	2015	Both	Scotland	Scottish Government
2012 National Atmospheric Emissions Inventory (NAEI) Large point sources. **F**uel consumption data which underlies the NAEI (fuel consumption split by fuel type for each plant for sites included in the inventory which are mainly large and include sites participating in the EU-ETS).	2012	Non-Domestic and DH	UK	NAEI Complied by Ricardo E&E
The Inter-Departmental Business Register (IDBR) For each of the 2.7 million employment sites in the UK: Address incl. postcode, number of employees including and excluding management, SIC Code (2003 & 2007), Grid Reference, Easting and Northing	2014	Non-Domestic	UK	Office for National Statistics (ONS)
OS Mastermap Topography Layer GIS files which give digital boundaries for every land feature in GB (each assigned a Topographical Identifier (TOID) with feature classifications including occupied buildings. Enables occupied buildings, boundaries of parks and other similar open areas to be located and measurement of their footprint areas using GIS software.	Sourced 2015 – updated biannually	Both	GB	Ordnance Survey (OS)
OS Mastermap Topography Building Height Attributes Gives Building heights in most large towns/cities areas in GB which would cover vast majority of population and high rise buildings and hence total building floor area. However omits some cities and large towns e.g. Aberdeen and Reading	2014	Both	GB	Ordnance Survey (OS)
OS Meridian2 (Roads) Open source GIS map of roads in GB used to locate and measure roads within potential DH Network areas	Sourced 2015 – updated biannually	Both	GB	Ordnance Survey (OS)

Name and description of data source	Date of data	Domestic/ non-domestic	Geographic coverage	Source (organisation/ programme)
AddressBase Premium. Gives numerous fields of information including URPN, coordinates and partial mapping to Mastermap TOIDs for every address in GB Including house/building type and sector	Sourced 2015 – 6 weekly refresh	Both	GB	Ordnance Survey (OS)
Built-Up Area Boundaries GIS files which give boundaries of Contiguous Built up areas in England & Wales >20 Ha including built areas separated by open spaces <200m apart	2014	Both	E&W	Office for National Statistics (ONS)
Scottish Settlement Boundaries GIS files which give boundaries of Contiguous Built up areas in Scotland with ≥500 people	2012	Both	Scotland	NRS
Northern Ireland Settlement Development Limits (SDL) GIS files which give boundaries of settlements with a population in excess of 1,000	2005	Both	NI	NISRA
LPS Property Data products Gives floor areas for dwellings and rateable value (NAV) for non-domestic buildings in Northern Ireland Additional non-domestic floor area data obtained from LPS separately.	2014	Both	NI	LPS
OSNI Pointer Gives numerous fields of information including URPN, coordinates and partial mapping to Mastermap TOIDs for every address in NI Including house/building type and sector	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)
OSNI Road Network Product Open source GIS map of roads in NI used to locate and measure roads within potential DH Network areas	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)
OSNI 1:50 000 Vector Scale Product A mid-scale view of Northern Ireland used to locate built-up area boundaries in Northern Ireland	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)
OSNI Regional Map Product Used to locate built-up area boundaries in Northern Ireland	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)
OSNI Global map Used to locate and name built-up areas in Northern Ireland	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)
OSNI Boundary Map Used to locate ward boundaries in Northern Ireland	Sourced 2015	Both	NI	Ordnance Survey Northern Ireland (OSNI)

Name and description of data source	Date of data	Domestic/ non-domestic	Geographic coverage	Source (organisation/ programme)
NI Super Output Area Boundaries Used to locate SOA boundaries in Northern Ireland	2011	Both	NI	NISRA
Non-Domestic Gas Availability Zones A derived dataset from a combination of NAEI and DECC sources (Geographical Data 1km x 1km resolution on gas use used to allocate between gas/coal and oil	2013	Non-Domestic	UK	NAEI complied by Ricardo E&E
Smoke Control Area Boundaries A derived dataset from NAEI and Defra sources (Geographical Data on smoke control areas used to allocate between gas/coal and oil)	2013	Both	UK	NAEI complied by Ricardo E&E
Cooling Indicators from CIBSE Guide F: Energy Efficiency in Buildings 2012 Average annual cooling electricity consumption per square metre and COP for various building types	2012	Non-Domestic	UK	CIBSE
CHPQA Data Used to estimate heat and fuel consumed by existing CHP schemes in consumption calculation process.	2012	Non-Domestic and DH	UK	CHPQA complied by Ricardo E&E
Survey data on Existing District Heating and Cooling Schemes for DECC Includes scheme and owner name and address, Total DH plant capacity, annual heat/cooling output, length of network, and numbers of buildings served by type. Used in heat consumption and new DH calculations.	2015	Both	UK	Survey by Ricardo E&E for DECC
Heating Supply Options for New Development – An Assessment Method for Designers and Developers' report for Scottish Government. Used for costing DH network components.	2009	N/A	Scotland	Parsons Brinkerhoff
The Potential and Costs for District Heating Networks' report for DECC. Used for costing DH network components.	2009	N/A		Poyry, Faber Maunsell and AECOM
Report on costs of DH by AECOM/underlying assumptions for DECC Used for costing DH network components.	2014	N/A		DECC
The Interdepartmental Analysts' Group (IAG) Toolkit 2014 Techno-economic projections designed for energy policy modelling for various energy and energy policy parameters including Long Range Variable Costs for different fuels including electricity and the social cost of carbon and air quality impacts.	2014	Both	UK	DECC
Bespoke Gas CHP Policy– Cost curves and Analysis of Impacts on Deployment' Report for DECC URN: 14D/416. Used for developing Gas CHP techno-economic assumptions	2014	N/A	UK	Ricardo E&E

Name and description of data source	Date of data	Domestic/ non-domestic	Geographic coverage	Source (organisation/ programme)
July 2014 UEP Modelling. Used for developing renewable CHP techno-economic assumptions	2014	N/A	UK	Ricardo E&E
RHI Reports and underlying datasets Used for developing renewable heating techno-economic assumptions	2011	Both	UK	Ricardo E&E
DUKES Chapter6 and underlying renewable data from RE-STATS Used to establish existing renewable heating capacity	2010-13	Both	UK	DUKES and underlying data from RE-STATS held by Ricardo E&E for DECC
Research on the costs and performance of heating and cooling technologies', Sweett Group Feb2013 Used for developing renewable heating techno-economic assumptions	2013	Both	UK	Sweett Group
DUKES 2014 Chapter 5 (Power Station Data Sep 2013) Used to estimate heat extraction potential from existing power stations	2013	N/A	UK	DECC
Environmental Permits EA (Data on Energy from Waste Schemes in England Used to estimate heat extraction potential from existing energy from waste schemes	2015	N/A	England	EA
Environmental Permits SEPA Used to estimate heat extraction potential from existing energy from waste schemes	2015	N/A	Scotland	SEPA
Environmental Permits WAG Used to estimate heat extraction potential from existing energy from waste schemes	2015	N/A	Wales	WAG
Data on Energy from Waste Schemes in Northern Ireland Used to estimate heat extraction potential from existing energy from waste schemes	2015	N/A	NI	NI DETI
The potential for recovering and using surplus heat from industry' study by Element Energy, Ecofys and Imperial College for DECC. Used to estimate industrial waste heat potential	2014	N/A		DECC
DCLG 'Table 401: Household projections, United Kingdom, 1961-2037 Used to project domestic building stock growth to 2025	2012	Domestic	UK	DCLG
DECC Updated Energy & Emissions Projections - September 2014: Annex F: Final Energy Demand: Used to project heat consumption to 2025.	Project to 2035	Both		DECC

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