Report to the Scottish Government

Scenarios for Scottish Heat

Heat Pathway Scenarios Model Factual Report

231957-4-05-03

Issue 4 | 29 May 2014

Job number 231957-00

Ove Arup & Partners Ltd
13 Fitzroy Street
London
W1T 4BQ
United Kingdom
www.arup.com

ARUP

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List of Acronyms

ASHP	Air-source heat pump
CCS	Carbon capture and storage
CHP	Combined heat and power
CO_2	Carbon dioxide; a greenhouse gas
CO_2e	Carbon dioxide equivalent; expresses the global warming potential of GHGs relative to CO_2
DECC	The UK Department of Energy and Climate Change
DEMScot	The Domestic Energy Model for Scotland
DEFRA	The UK Department for the Environment, Food and Rural Affairs
DH	District Heating
DHW	Domestic Hot Water
EfW	Energy from waste
ECO	The Energy Company Obligation
EST	Energy Saving Trust
GHG	Greenhouse gas (used interchangeably with CO_2e)
GHGI	Greenhouse gas inventory
GSHP	Ground-source heat pump
GI	Government Intervention; scenario model driver
HEEPS	The Home Energy Efficiency Programmes for Scotland
HGPS	(Draft) Heat Generation Policy Statement
HPSM	Heat Pathways Scenario Model
IEA	International Energy Agency
MAC	Marginal GHG Abatement Cost (see Section 3.3.2)
NAC	Net Annual Cost (see Section 3.3.2)
RHI	Renewable Heat Incentive
RHPP	Renewable Heat Premium Payment
RPP2	The Second Report on Proposals and Policies
SAP	The UK Government's Standard Assessment Procedure
SBEM	Simplified Building Energy Model
SEPA	Scottish Environmental Protection Agency
SHCS	Scottish Housing Condition Survey
SPRI	Scottish Pollution Release Index
UEP	(DECC) Updated Energy Projections
UT	Uptake; scenario model driver

Units

GW	Gigawatt; a unit of power
MJ	Megajoule; a unit of energy
$MtCO_2e$	Megatonnes of CO_2-equivalent; a unit of greenhouse gas emissions
TWh	Terrawatt-hour; a unit of energy

Executive Summary

Arup was commissioned to develop a numerical model which can allow the Scottish Government to explore scenarios and pathways for decarbonisation of heat up to 2050. The work is intended to be used by the Scottish Government to assist in developing its planned Heat Generation Policy Statement[1]. The study covered demand for heating, hot water, catering and cooling in Domestic and Non-domestic sectors, as well as Industrial process heat.

It was agreed with the Scottish Government at the commencement of this study that the two “critical uncertainties” to future uptake of decarbonisation measures were the level and nature of Government Intervention and that of Uptake out to 2050.

Government Intervention (GI) represents action by Government either to mandate or incentivise uptake of measures to reduce energy demand and to increase switching to lower carbon supply technologies.

Uptake (UT) can be understood to represent a change of attitude of individuals and businesses which results in a greater willingness to overcome barriers or override objections to the adoption or uptake of available lower carbon demand and supply measures.

These two drivers combine to form four scenarios – Low/Low, Low/High, High/Low and High/High. In addition, a Reference scenario was modelled along the lines of the Scottish Government’s policies contained in *Low Carbon Scotland: Meeting the Emissions Reduction Targets 2013-2027. The Second Report on Proposals and Policies* (RPP2). This Reference scenario attempts to describe a narrative of policies and milestones indicated within RPP2 as best as is possible within the modelling framework, but is not intended to be a direct representation of RPP2. All scenarios are based on a suite of assumptions derived from published data and previous research.

The key results of the scenario modelling are shown in the table and figure below. Comparisons for 1990 are against an estimated baseline.

Table 1. Scenario key outcome indicators

	2010 Value	Reference Scenario	1: Low GI, Low UT	2: Low GI, High UT	3: High GI, Low UT	4: High GI, High UT
GHG change by 2050 vs. 2010 (% change)	N/A	-56%	-43%	-69%	-68%	-81%
GHG change by 2050 vs. 1990 (% change)	17%	-64%	-53%	-74%	-74%	-84%
Net Cumulative Costs* vs. Reference Scenario (% change)	N/A	N/A	+1.7%	+0.2%	+4.4%	-0.4%
% of Renewable Heat** by 2020 (target = 11%)	N/A	12%	11%	14%	11%	14%

Notes: *Net cumulative costs are the sum of cumulative CAPEX and total cumulative OPEX over the period 2010 – 2050 relative to the reference scenario. **Defined as the delivered renewable heat divided by the total delivered heat from non-electric sources.

[1] Differences in the cost figures in this report and the draft Heat Generation Policy Statement (HGPS) result from on-going refinement and development of the heat model since the draft HGPS was published. Further development of the heat model will likely result in further refinements to modelled estimates going forward.

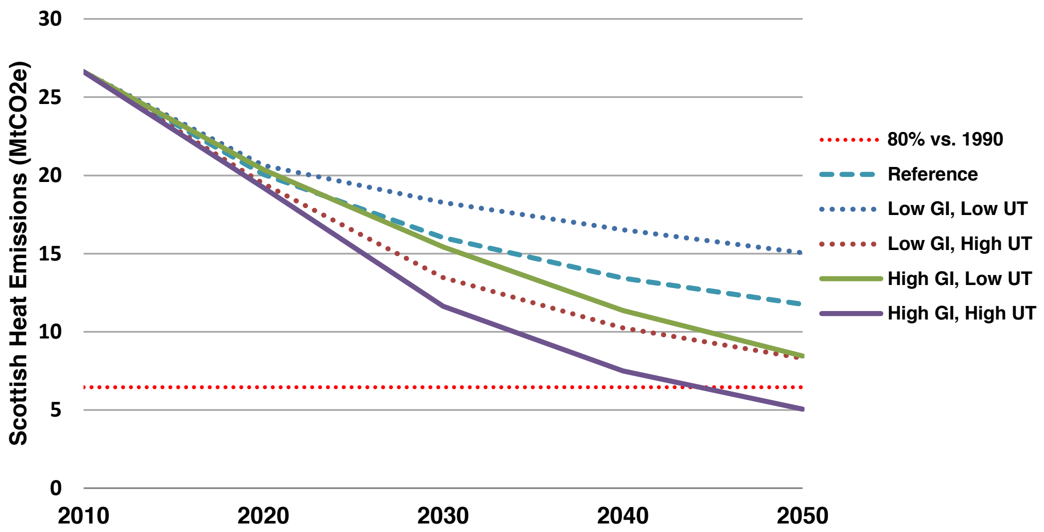

Figure 1. Summary graph of pathway scenarios[2]. GI = Government Intervention, UT = Uptake.

Key messages

The scenario analysis provides clear messages that High levels of both GI and UT are required to achieve the greatest carbon reduction in the most cost-effective way (see rows 1 and 3 of Table 1). In practice this means sustaining government support for low-carbon heat technologies through the entire period modelled and ramping up public information campaigns and engagement to ensure High UT.

With High GI alone it is possible to achieve major additional decarbonisation over the Reference scenario. However, with Low UT this comes at a greater overall cost than in the Reference scenario. When coupled with High GI, High UT leads to total costs which are £16.7bn (4.6%) lower than with Low UT, and £1.5bn (0.4%) lower than under the Reference scenario. The High GI, High UT scenario also achieves the greatest overall decarbonisation of heat. It is also clear that a Low GI, Low UT scenario results in far poorer emissions reduction performance relative to the Reference case. It should be noted that some level of government intervention would in reality be associated with a high level of UT, but these two drivers are modelled separately in this work.

All the scenarios indicate achievement of the 2020 renewable heat target. This is because of the momentum already in the system which is being sustained or even accelerated by government plans already representing a relatively high level of government intervention. The scenarios therefore do not show much sensitivity in the short term.

The scenarios that achieve significant heat decarbonisation involve high reductions in heat demand through retrofit of existing stock and improved thermal

[2] It is important to note that the heat emissions figures presented in this report for 1990, the 2010 baseline year, and emissions abatement are not directly comparable to the corresponding heat emissions figures presented in the Second Report on Proposals and Policies. The heat emissions in this report are based on a definition of heat that includes traded and non-traded emissions across domestic and non-domestic buildings and industrial process. It also includes the indirect emissions from electric heating. The heat emissions figures presented in the Second Report on Proposals and Policies are less disaggregated and based on non-traded source emissions only.

performance of new development. On the supply side, GHG reductions are achieved through switching on a large scale from high-carbon supplies, such as oil and coal boilers, to low-carbon supply technologies, such as district heating, biomass, and heat pumps. However, heat pumps and other electric heating technologies such as storage heaters only achieve material carbon reductions in association with a significantly decarbonised electricity grid. It should be noted that electricity grid modelling and non-heat electricity consumption were not part of the scope of this study and that all scenarios apply DECC projections that the electricity supply is essentially decarbonised by 2050.

Related to this, the impact upon the electricity grid of wholesale switching to electric heat varies significantly from scenario to scenario, with some scenarios adding considerable peak load burdens to the grid. The grid impacts, particularly cost, have not been considered as part of this commission, but should be investigated to gain a full understanding of the implications of these scenarios. Given that total heat demand met by non-electric sources in Scotland is almost three times total electricity demand, reliance on a future grid whether decarbonised or not, for a much larger share of Scotland's heat demand, will put significant pressure on the transmission and distribution networks and the pipeline of new generation.

Additional Observations

The following observations are made from the results of these pathway scenarios. Note that they depend on particular assumptions (around technology costs, fuel prices, uptake rates etc.), and certain fixed exogenous drivers. In reality, shocks and spikes in the future could lead to rapid changes, the potential for which cannot be readily analysed in these few modelled scenarios.

- As expected, all scenarios show some level of decarbonisation of heat delivery, enabled in particular by the assumed decarbonisation of the electricity grid.
- Compared to an estimated 1990 heat emissions baseline of 32.3 MtCO2e, by 2010 Scotland's emissions from heat had already reduced by some 17%. Despite this, only the High GI, High UT scenario is able to exceed an 80% emissions reduction against a 1990 level.
- Electricity grid decarbonisation is essential to the overall achievement of radical GHG reductions by 2050. Modelling indicates that the greatest reduction achievable, should the grid not fully decarbonise, is 62% vs. 2010, with the Low GI, Low UT scenario only delivering 29% annual GHG savings by 2050. By contrast, the highest reduction achieved in a scenario including grid decarbonisation is 81%. Note that the costs of electrical grid decarbonisation have not been taken into account in this analysis.
- GI alone (as modelled) enables moderate heat decarbonisation, but can realise an additional 13 percentage point GHG reduction by 2050 when coupled with high UT.
- The Reference scenario, representing a combination of high GI up to 2020, and moderate GI and UT thereafter, closely follows the High GI, Low UT scenario trajectory until 2030.
- The costs of decarbonising heat are significant, with the greatest emissions reduction scenario requiring around an additional £16bn (15%) of capital spending compared with the Reference scenario. On the other hand, on a net (cumulative capital and operational) cost basis, the highest reduction scenario

is also the most cost-effective, largely as a result of the reductions in energy demand associated with it.

- While there are notable differences between all scenarios for capital and operational costs individually, when combined, cumulative capital and operational costs out to 2050 do not show the same variation, and are very similar. Despite these similar costs, however, there are markedly different carbon emissions reductions seen across the scenarios, suggesting that managing overall costs is not the primary challenge for Government, but instead that driving demand reduction, stimulating Uptake and overcoming resistance to novel technologies are more important means of achieving a decarbonised heat sector.
- In the greatest emissions reductions scenario (High GI, High UT), total electrical demand (TWh) for heat increases by 32% when compared with the Reference scenario, but the High GI, Low UT scenario demands an additional 56 percentage points over the High GI, High UT scenario when compared to the reference scenario, with significant implications for generation, transmission and distribution infrastructure.
- If high GI (as modelled) is not accompanied by high UT, winter peak shock electricity demand could be expected almost to quadruple. This is a result of the scenario conditions leading to higher uptake of inefficient simple electric heating technologies as opposed to more efficient, heat pump-based heating systems.

Scenario narratives

Summaries of the outcomes of each of the five modelled scenarios are provided below. These are stories woven around the numbers generated by the model. They are plausible alternative futures but none of them purports to be predictions of what will happen. Additional detail on each scenario is provided in the main body of the report.

Reference Scenario

From a 2010 Scottish heat emissions baseline of 26.6 $MtCO_2e/yr$[3], the Reference scenario sees overall heat emissions fall by 14.9 $MtCO_2e/yr$ (56%) by 2050. By 2030 significant decarbonisation of heat has already been achieved, with a reduction in heat emissions of 40%; however, after this point the pace of heat decarbonisation slows somewhat.

Moderate GHG reductions are made across all sectors. The domestic sector in particular reduces its emissions by over 60% through a reduction in overall demand for heat (around 20%) despite continued growth in new housing, and a growth in the use of modern electric heating (heat pumps) from 2020 onwards. The non-domestic buildings sector achieves similar reductions in emissions, despite overall demand remaining unchanged by 2050. The Industrial sector achieves an emissions reduction of around 50% through fuel switching and efficiency measures.

Fabric retrofit of existing domestic and non-domestic buildings is a key enabler for overall emissions reduction; this helps to ensure that heat demand does not show a net increase despite new additions to the stock.

[3] The build-up of this baseline is described in Section 7, with the data outlined in Section 4.1.

In the domestic sector, reliance on gas boilers, resistive heating (such as storage heaters) and oil-fired boilers has reduced by 2020. In later decades, heat pumps are the most significant additional low-carbon heat source, along with district heating. Through to 2050 modern, condensing gas boilers continue to supply the majority of domestic heat.

The non-domestic sector is more responsive to signals from government than the domestic sector in the first decade, but gas boilers remain a significant energy source. However, these are mostly modern, condensing types by 2020. The share of gas heating remains steady to 2050, with heat pumps, biomass boilers, and low-carbon district heating supply taking over from higher emissions solid- and liquid-fuelled systems.

Scenario 1: Low GI, Low UT

The Low GI, Low UT scenario's trajectory to 2050 is dominated by consumers' tendency to assess technologies based on their lifetime costs (capital, maintenance and fuel costs) alone and not on their GHG abatement potential, and a desire to continue with existing, familiar means of heat delivery. As a result, a moderate heat emissions reduction of only 11.6 $MtCO_2e$/yr (43%) is achieved by 2050. This is the lowest GHG reduction of any of the scenarios, and is 22% less than that of the Reference scenario.

Within the Domestic sector, low public uptake of fabric retrofit measures within the existing stock and limits to implementation of further improvement in new-build standards through regulation leads to residential heat demand remaining essentially constant between 2010 and 2050.

There is an initial high level of uptake of novel heat-supply technologies to 2020, as a result of existing policies and trends, which displaces old gas boilers in particular. District heating schemes are among the growing alternative solutions during this first decade.

However, over the 2020-2030 decade consumer behaviour leads to a rebound in the use of gas heating, with only heat pumps and district heating competing significantly for a portion of total supply.

Heat supply in the non-domestic sector follows similar trends to the domestic sector, with modern gas boilers retaining the majority share of heat provision. However, biomass energy, heat pumps, and district heating claim a greater share of overall generation by 2050 than in the domestic sector.

Scenario 2: Low GI, High UT

The Low GI, High UT scenario gives the second highest GHG reduction potential of all five considered scenarios, reducing baseline 2010 heat emissions by 18.3 $MtCO_2e$/yr in 2050 (69%). This is a 23% greater reduction than the Reference scenario.

Low levels of government regulatory intervention result in significant deferral of stronger regulatory provisions for new-builds, but high Uptake drives forward retrofit, such that total heat demand is reduced significantly for the domestic sector. Heat demand reduces for the non-domestic sector, driven mainly by refurbishment of existing commercial building stock. Public buildings, however, do not see significant refurbishment due to the Government not leading by example.

Consumers in the domestic sector opt increasingly for heat pump solutions after 2020, and district heating plays a growing supply role. The contribution from gas boilers reduces from around 75% in 2010 to around 35% in 2050.

In the non-domestic sector Uptake similarly drives a high uptake of low-carbon technologies, with biomass heating accounting for a very significant fraction (over a third) of total heat generation. Heat pumps and district heating are also strongly represented, ensuring that low carbon heat supplies over 60% of all demand.

Scenario 3: High GI, Low UT

The High GI, Low UT scenario indicates a total GHG reduction by 2050 of 18.2 $MtCO_2e$/yr (68%), which is 22% greater than that in the Reference scenario. While Government has succeeded in ensuring consumers choose heat supply technologies on the basis of their marginal GHG abatement cost (MAC), a low level of Uptake acts as a drag on technology switching.

After 2030, in both the Domestic and Non-domestic sectors there is a rising uptake of simple electric heating (e.g. storage heaters), such that by 2050 it is contributing almost 30% of the Domestic heat demand, leading to a considerable additional load on the electricity grid (see Table 1). This trend is primarily due to the relatively low price and simplicity of the technology and the benefits of electrical grid decarbonisation rendering it "low carbon". It is also driven by consumers' resistance to new heating technologies such as heat pumps assumed in the scenario. Because simple electric heating is not the most efficient way of delivering heat via electricity, this scenario is somewhat of a challenge from an electrical grid infrastructure perspective; it requires significantly higher electrical generation and capacity reserves, which will be difficult to ensure alongside grid decarbonisation targets.

Refurbishment activity for the existing domestic and non-domestic sectors is relatively low, but high enough to prevent net increases in heat demand due to new-build stock additions, so no overall decrease is realised. The new-build stock for domestic and non-domestic buildings is pushed through regulatory means that ensure additions are highly energy efficient and any net emissions are offset by 2019 in both sectors.

In the industrial sector, CCS technology sees uptake by 2050 due to Government Intervention drivers, but low Uptake means heat is still delivered by the same sources as in 2010.

Scenario 4: High GI, High UT

The High GI, High UT scenario represents the greatest level of heat decarbonisation. Emissions by 2050 are 21.6 $MtCO_2e$/yr (81%) lower than the 2010 baseline, and represent a 45% greater reduction by 2050 compared to the Reference scenario.

Overall demand for heat in the non-domestic sector is reduced to 2050 by improved energy efficiency (through refurbishment) in the existing stock, which more than offsets efficient new-build additions (the emissions of which are kept low through regulation); the sector as a whole is able to achieve a GHG emissions reduction of some 85% over the 40-year period.

Emissions in the domestic sector are reduced by 89%. This is achieved by a reduction in total heat demand of over 30% driven by strong retrofit and tightened regulations for new-build, and a near complete transition away from on-site combustion of fossil fuels. On-going government support for heat pumps in particular allows them to achieve 48% of the total supply mix.

Particularly in the domestic sector, modern electric heating technologies, i.e. heat pumps, have a very significant role, providing 57% of all heat. Whilst far more efficient than simple electric heating (such as storage heaters), heat pumps in this scenario do still lead to increased electrical demands and capacity requirements compared to the Reference scenario; winter peak shocks could lead to nearly twice the available electrical capacity required in 2010, but electrical consumption is only 32% higher. Notably, the demands on the electrical infrastructure for this scenario are far less high than in the High GI, Low UT scenario.

District heating plays a notable role in domestic and non-domestic sectors. In the non-domestic sector, in particular, renewable heat district heating networks supply 21% of heat demand met by renewables. Biomass gains a very substantial share of the non-domestic market by 2050 under this scenario, supplying over 40% of all energy for space heating and hot water.

Industrial sector emissions are reduced by 74% by 2050 through the application of carbon capture and storage (driven by high Government Intervention) and significant fuel switching away from fossil fuels to cleaner natural gas, electricity and biomass.

1 Introduction

1.1 Context

In 2009, the Scottish Parliament unanimously passed climate change legislation which committed Scotland to achieving an 80% reduction in greenhouse gas (GHG[4]) emissions from a 1990 baseline by 2050 and a 42% reduction in emissions by 2020. In response to these commitments, the Scottish Government has been steadily developing its evidence base and policy framework to drive a transformation in the way we generate and use energy.

Various heat policy commitments have now been drawn together into the Scottish Government's Outline for a Draft Heat Vision[5], published in January 2013. The document seeks to articulate a vision which goes beyond the existing Renewable Heat Action Plan to something more holistic (addressing both renewable and non-renewable heat sources) and which looks further into the future. The document's resulting "statement of ambition" is set out below:

> *By 2050 Scotland will have a largely decarbonised heat sector with significant progress made by 2030. This ambition will be realised through a number of means, including renewables and CCS, but is based on the fundamental first principles of keeping demand to a minimum, most efficient use of energy and recovering as much "waste" heat as practically possible, at least cost to consumers.*

Notwithstanding these various strategy and policy documents, there is not yet a clear overarching policy framework for how the vision will be achieved.

Arup was therefore commissioned to develop a model which can allow the Scottish Government to explore scenarios and pathways for decarbonisation of heat up to 2050. The work is intended to assist the Scottish Government to develop a Heat Generation Policy Statement.

The main elements of this commission were:

- production of an Excel-based pathway scenarios model of the Scottish heat system covering domestic, non-domestic and industrial sectors and the period 2010-2050;
- development of a range of plausible heat generation scenarios to 2050 consistent with the Scottish Government's GHG targets;
- engagement with key stakeholders to obtain external input into the scenario development work; and
- final production of a scenarios report.

The project was overseen by a Steering Group made up of relevant staff from Scottish Government and Scottish Enterprise.

[4] The term greenhouse gas (GHG) refers to the Kyoto Protocol "basket" of substances (natural and anthropogenic) recognised by the international scientific community as drivers of potential climate change. (http://naei.defra.gov.uk/overview/ghg-overview). GHGs at the scale of a country are normally measured in units of megatonnes CO_2 equivalent ($MtCO_2e$). Although often used interchangeably, with "CO_2" and "carbon", the use of "GHG" is preferred as being more accurate.

[5] http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/Heat/DraftHeatDeployment

1.2 Purpose and scope of report

This document provides a factual report of the work undertaken by Arup and describes the scenarios which have been developed within the pathway scenarios model.

2 Method

This section describes the scope and method undertaken to develop the model and scenarios.

2.1 Model Scope

The scope of the Heat Pathways Scenario Model (HPSM) covers all heat use and generation within Scotland associated with the use and occupation of buildings. This includes space heating, hot water supply, cooking, and industrial process heat. Cooling is also included in the non-domestic sector. The time range of the model is from 2010 to 2050.

The model is centrally concerned with the impact on GHG emissions from changes in building thermal performance and in the way heat is generated across the whole of Scotland. It does not provide a breakdown by type of user or by specific geographical area.

The "heat system" for Scotland has been broken down in the model into the following sectors and geographical categories:

For domestic and non-domestic buildings:

- Existing and new buildings
- Urban areas, rural areas gas grid connected and rural areas off-gas grid
  Urban / rural classification is according to the Scottish Government's classification system[6]*, whilst gas grid connectivity for Rural areas was evaluated from analysis of data held in the 2007 Scotland Heat Map*[7]*. These geographies are indicated in Figure 2 on the next page.*
- Demand measures and supply measures

For industrial facilities:

- Minerals sector
- Metals sector
- Chemicals sector
- Other sectors

[6] http://www.scotland.gov.uk/Topics/Statistics/About/Methodology/UrbanRuralClassification
[7] http://www.scotland.gov.uk/About/Information/FOI/Disclosures/2007/10/AEAHeatMap2007

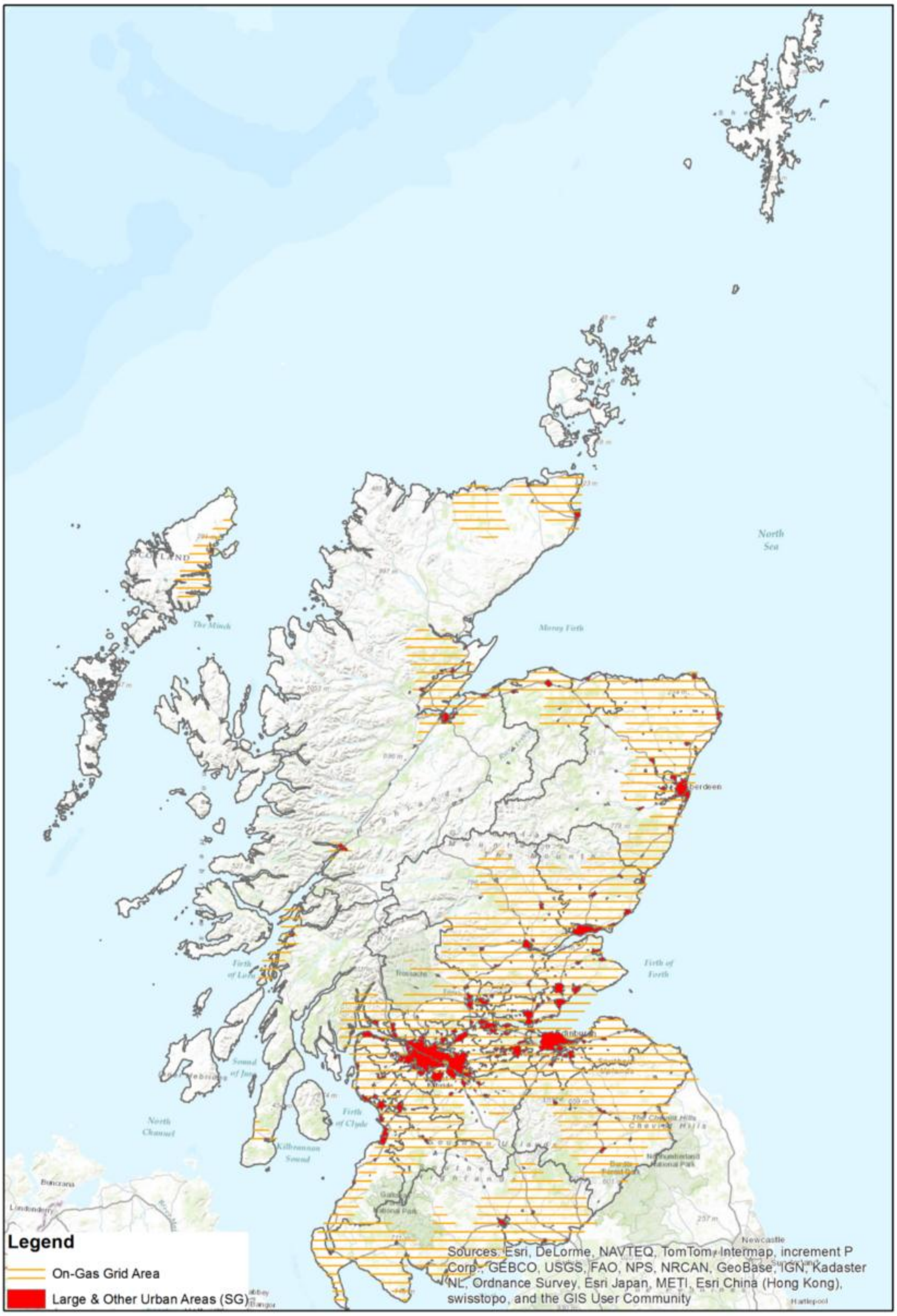

Figure 2. Classification of Scottish Heat Geographies.

Notes: Urban Rural classification as per the Scottish Government's classification[8]. Urban areas are indicated in red. Rural on-grid areas are those falling within the "On-Gas Grid Area" boundaries. Rural Off-grid areas are those which fall outside these boundaries. Note Statutory Independent Undertakings (SIUs) are considered as grid-connected, although they are stand-alone networks, and are indicated as having the potential for future grid expansion.

8 http://www.scotland.gov.uk/Topics/Statistics/About/Methodology/UrbanRuralClassification

The model does not include:

- Electricity consumption and supply for non-heat uses;
- Heating for agricultural and horticultural purposes;
- Heating associated with transport; or
- Direct emissions from industrial processes themselves, e.g. CO_2 released through limestone calcination in cement manufacture.

2.2 Purpose of the scenarios model

Scenario models, whether forward or backward casting, are a useful tool to investigate the potential sensitivities and uncertainties associated with future developments of a given set of interlinked variables.

The HPSM is a forward projection model intended to analyse the range of plausible heat emissions scenarios to 2050. The scenarios vary according to changes within the two main drivers or critical uncertainties, being Government Intervention (GI) and Uptake (UT). Within each driver are many specific variables which combine to generate pathways of heat use and generation over time. The values of these variables can be adjusted to reflect a range of states from "high" to "low". It is a means of visualising and conceptualising the potential scale of the efforts required to deliver a decarbonised heat supply and its wider benefits. We believe this report and the tool itself will be particularly useful in helping the Scottish Government and other actors in understanding:

- How subsidies and other government interventions may influence private actors' decisions about heat demand reduction investments and supply technology selection decisions.
- The importance of other factors, such as public acceptance (across domestic, non-domestic, and industrial sectors) of non-conventional and low carbon options and other energy-related behaviours, on uptake rates.
- The scale of the change and investment required to achieve targets;
- The potential impact on the electricity grid of changes to how heat is generated; and
- The quality and extent of data related to current and future heat use and generation.

The tool sits as part of a wider Scottish and UK evidence base on climate change mitigation efforts that will inform policy makers and the public going forwards.

With this in mind, it is important to reflect on what the HPSM is not:

- With the exception of the early years of the Reference scenario, the HPSM does not purport directly to reflect any current Scottish Government policies or proposals and their future potential. Even in the case of the Reference scenario, this model does not represent a roadmap for delivering the commitments in RPP2. The indicated split of domestic heating technologies, for example, is not a "recommended" pathway. It is merely one of a number of possible scenarios that could meet the Scottish Government's targets; GHG emissions and renewable heat in particular.
- It does not supersede any modelling and projections presented in RPP2 itself.
- It is not a detailed technology and intervention model and should not be used to draw detailed conclusions about sub-sectors and sub-regions in Scotland.

- It is not a means by which to choose "winners" in the race to decarbonise Scotland's heat supply. The scenarios outlined do not represent a preferred or expected heat generation mix, rather a plausible mix based on the assumptions modelled.
- It is not an assertion about how the future *will* unfold.

2.3 Relation to other models

The HPSM joins the ranks of numerous energy models which apply to Scotland or the UK as a whole. Some of these have served as inputs or as the basis of calculation of some data included in the HPSM, while others would be able to use the HPSM outputs as inputs for their purposes. The table below identifies and comments on the main related or comparable models of which Arup is aware.

Table 2. Relationship of HPSM to other models

Name of model	**Scope and purpose of model**	**Relationship to HPSM**
DEMScot	The Scottish Government's Domestic Energy Model, updated in 2010. It contains a relatively detailed database of the Scottish housing stock that was compiled in 2006, and uses this to investigate the effects of various measures on domestic heat demand and GHG emissions. It uses the SAP energy modelling framework. Very useful for evaluating the potential of programmes that influence individual measures or small measure baskets.	DEMScot is used in the HPSM to characterise the Scottish existing domestic building stock. It is coupled with Scottish Housing Condition Survey data and Scottish Government inputs to bring data on the condition of the stock up to date. DEMScot, using updated information, remains the preferred means by which to assess emissions reduction potential of individual measures and policy impacts in the Scottish housing stock.
SAP / SBEM	The UK Government's Standard Assessment Procedure (SAP) is used to evaluate the energy, emissions, and fuel cost characteristics of dwellings. SBEM is a tool developed by BRE that is used in support of the National Calculation Methodology to evaluate the energy performance of non-domestic buildings. Its focus is on regulated energy use and CO_2 emissions. Both tools use a range of standard assertions on occupancy and use of buildings and are used both to produce Energy Performance Certificates and demonstrate compliance with building regulations.	SAP calculation forms the basis for the energy demand baseline and is used to estimate the impact of demand measures for retrofit and new build. Values generated in the HPSM do not, however, directly reflect SAP scores and performance, because of necessary simplifications in the HPSM. SBEM is used to evaluate the performance of new non-domestic building archetypes with varying fabric standards.
DECC 2050 Pathways Calculator	DECC's 2050 Calculator is a UK economy-wide energy and emissions supply and demand model. It covers all sectors that contribute to the UK's domestic GHG emissions. By altering the level of intervention for a wide range of drivers, a huge variety of pathways are generated. A significant value is its transparency; the model is open-source, still updated a number of years after its initial release, and informed by a wide body of stakeholders assembled during a call for evidence in 2011.	Heat supply and demand reduction technologies considered in the HPSM are broadly similar to those in the Pathways Calculator. Costs used in the Pathways Calculator are a source of data for the measures considered in the HPSM. Some sections of the original calculation methods used by DECC are replicated or emulated in the HPSM.

3 Model Architecture

The HPSM was designed as a Microsoft Excel-based energy technology uptake model. It enables users to understand the likely GHG emissions and the sum of costs of different pathways towards a lower carbon means of generating and supplying heat to Scottish buildings and occupiers/users.

3.1 Structure Overview

The figure below provides an overall picture of the conceptual structure of the model.

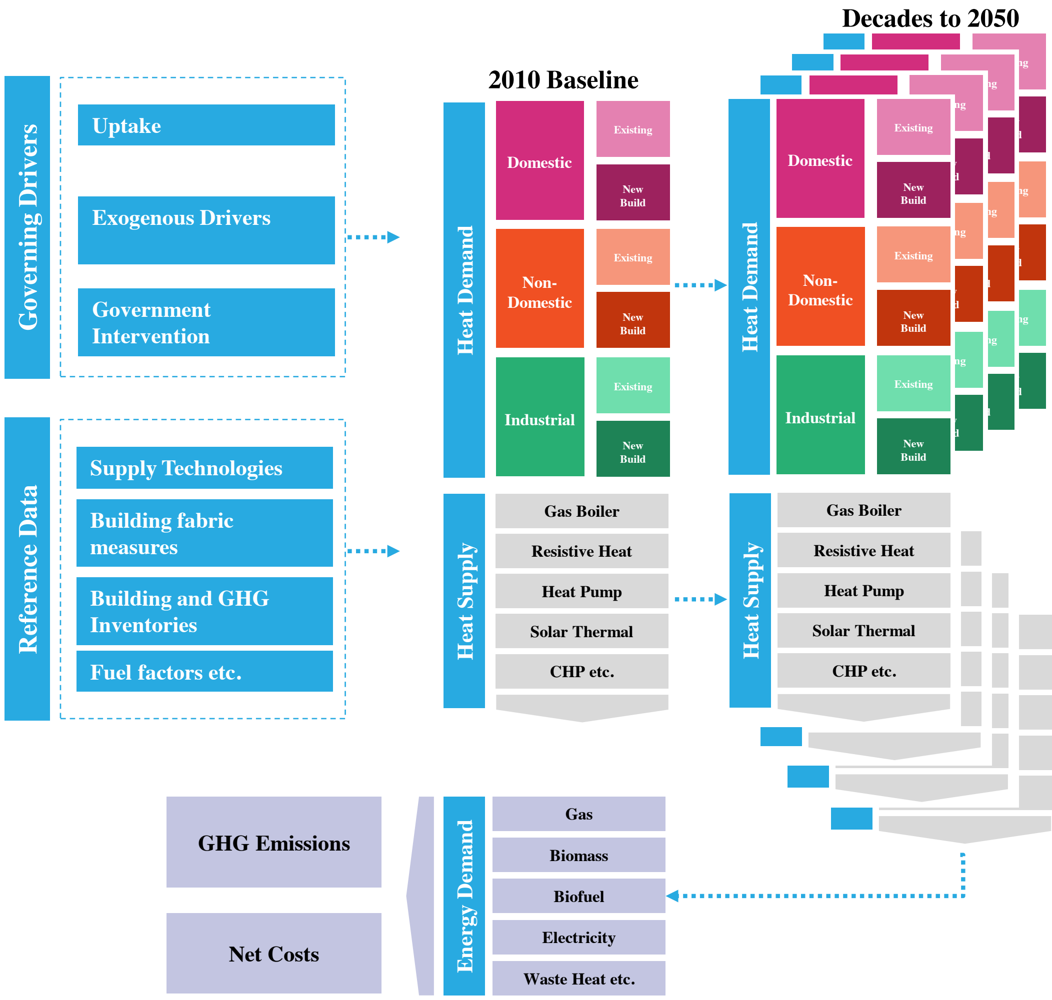

Figure 3. Model structure

As indicated in the Figure 3, the core calculation part of the model comprises demand and supply measures modules which are replicated for each decade. The uptake of these measures within these modules is influenced by a combination of exogenous drivers and the key endogenous drivers of "Government Intervention" and "Uptake". The model is designed for scenarios to be created around low and high levels of each of these two drivers.

From the 2010 baseline, the outputs of each decade's selected uptake of demand and supply measures leads to the calculation of energy/fuel demand and thence to

GHG emissions. Each decade's measures, along with changes in stock, result in a new baseline of demand and supply for the subsequent decade, leading to the final 2050 outcome of GHG emissions and total costs for each scenario.

The performance and potential uptake of different measures draws upon the model's extensive reference data which includes technical and cost performance data on different measures as well as baseline information on buildings and industry.

3.2 Notes on key scenario drivers

It was agreed with the Steering Group at the commencement of this study that the model would allow two "critical uncertainties" to future uptake of decarbonisation measures to be explored out to 2050: the level and nature of Government Intervention and of Uptake. The elements within each of these driver categories which are relevant to the model design and operation are briefly described below, and presented in full in Appendix A.

Government Intervention (GI) represents action by the Scottish, UK and local governments either to mandate or incentivise uptake of measures to reduce energy demand and to increase switching to lower carbon supply technologies. The actions available to governments include:

- Design requirements and construction standards implemented through Building Regulations and other regulatory provisions (for new and existing buildings), and Planning Policy;
- Prohibition or mandate of particular measures (such as mandating loft insulation), either universally or targeted to a particular geographical area or sector;
- Subsidy or grant, such as The Home Energy Efficiency Programmes for Scotland (HEEPS), the Energy Company Obligation (ECO) and the SME Resource Efficiency Scotland Loans for energy demand reduction, and the Renewable Heat Incentive (RHI) or the District Heating Load Fund to encourage switching to a low carbon heat supply;
- Charges and levies, such as the potential offsetting regimes associated with new development; and
- Requiring or encouraging homeowners, developers and businesses to choose technologies based on their cost of carbon abatement, rather than simple levelised costs.

Each of these types of measures can be reflected in the model, albeit at a level of granularity commensurate with the national scale of the model.

Uptake (UT) is more difficult to define and to model. Notwithstanding, it can be understood to represent a change of attitude of individuals and businesses – homeowners, landlords, facilities managers, plant operators etc. – which results in a greater willingness to overcome barriers or override objections to the adoption or uptake of available lower carbon demand and supply measures. This may also be achieved by the commercial sector adopting business models which remove real or perceived barriers. This change of attitude may be triggered by an increasing concern about global climate change or about energy security. Other triggers may be a change in perception of the value of savings achieved through uptake of demand measures or of the difficulty of switching to new supply technologies. A final potential trigger may be peer pressure or the snowball effect of accelerating uptake across the country. Particular dimensions of UT which can be modelled are:

- Willingness to adopt more costly technologies if they are lower carbon;
- Uptake rates of retrofit measures;
- Willingness to take up novel or unfamiliar technologies, such as ground source heat pumps or stirling engine micro-CHP to heat homes; and
- Changes in average internal temperatures within buildings.

One of the strongest drivers for reduced heat demand in domestic buildings is a reduction in "average" annual internal temperature. It should be emphasised that this does not necessarily push dwellings to being colder, especially when a large portion of Scottish households already experience fuel poverty[9]. Average temperature, as the name suggests, is an annual figure that is a product of thermostat set points, heating durations, whether all or some of the rooms in a property are heated and thermal losses in the building fabric, amongst other drivers such as external temperature. In other words, much can be done by householders and businesses to ensure that more of the heat generated by their heating systems is not wasted on unoccupied rooms or by dissipating into the atmosphere without any impact on their actual comfort levels.

At a UK level, average winter internal temperatures had been increasing relatively steadily since the mid-1980s[10], but have shown a moderate downward trend since 2005.

As an indicator of sensitivity to average annual internal temperature, a version of the model Reference scenario with a 5% reduction in internal temperatures by 2050 is able to achieve an additional 400,000 tCO_2e/yr reduction by 2050 compared to a case with no change in average internal temperatures.

Human attitudes and reasoning processes themselves cannot be directly modelled, or at least not within the modelling approach adopted for the HPSM. Therefore in general a future change in willingness to adopt demand or supply measures is expressed as a change to the maximum uptake rate against a defined baseline trend set for the 2010-2020 period.

3.3 Technology choice and uptake rates

3.3.1 Dispatch model

For the domestic and non-domestic sectors the amount of a given heat supply intervention (e.g. boilers or heat pumps) to be deployed over any decade depends first upon the life expectancy of heat supply equipment. Depending on the mix of technologies in the stock, a certain proportion of heat supply will have reached its end of life over the decade and will require replacement. Any new additions to the stock must also be supplied. Note, therefore, that the HPSM does not consider

[9] http://www.scotland.gov.uk/Topics/Statistics/Browse/Housing-Regeneration/TrendFuelPoverty
[10] https://www.gov.uk/government/publications/housing-energy-fact-file-2012-energy-use-in-homes

enforced switching of technologies that have not reached their end of life; all uptake rates are constrained by traditional plant replacement cycles.

3.3.2 Marginal abatement cost vs. net annual cost

The HPSM dispatches technologies to fill the required replacement / new-build demand according to ranking priorities defined by the Government Intervention driver level. These drivers and the rationale behind them are described in more detail in Section 6.

For low Government Intervention, consumers prioritise technologies with low levelised costs, i.e. capital, fuel and maintenance costs annualised over the technology's lifetime. These costs are referred to in the model as net annual costs (NACs), with units of £/kWh. Many hidden costs, such as administrative or management time, disruption etc. are not quantified.

For high Government Intervention, consumers are encouraged to prioritise technologies with low marginal abatement costs (MACs). MACs, quantified as pounds per tonne of CO_2-equivalent (£/tCO_2e) saved, are calculated in the same fashion as NACs, but now require an estimate of GHG abatement potential. A MAC is calculated by taking the difference in annualised lifetime costs of a technology (e.g. a new gas boiler) compared to the counterfactual (e.g. an old gas boiler) and dividing this by the amount of GHGs it saves compared to the counterfactual.

Crucially, MACs evolve in the future, as external drivers (costs, technological performance etc.) develop and internal constraints (number of households suitable for solar-thermal heating, remaining homes without loft insulation etc.) alter.

The HPSM investigates individual MACs by decade, for each sector, by geography, by existing and new-build stock, and for supply and demand technologies.

The Uptake driver controls how much of a given technology can be delivered over a given decade; once a technology's potential is exhausted, the model assigns the next best-ranked technology, and continues in this fashion until all demand has been met.

3.3.3 Calculating costs

Practically, a given technology's MAC should be calculated with an exact understanding of the counterfactual, i.e. the exact costs, efficiencies and emissions of the technologies it is replacing.

Given the number of calculations required for this model, the HPSM has been automated, calculating MACs based on an average counterfactual for the entire set (e.g. for heat supply measures applied to the entire existing rural on-grid stock of non-domestic buildings in 2020). The MAC values calculated are therefore not directly comparable with other studies of abatement potential within Scotland, but are appropriate for ranking systems according to relative performance in the HPSM due to their consistency in calculation.

3.4 Dealing with district heating

District heating is a key means by which to decarbonise heat supply where density of demand is sufficient to allow for the construction of viable networks. Typically the pattern is for new DH networks to be initiated with heat from fossil-fuel technologies (e.g. gas CHP and boilers). Once the initial generation plant is life expired, they can be replaced by lower carbon sources.

It has therefore been an important consideration that the potential for DH networks with a variety of heat sources is reflected in the model. However, doing so adds an extra layer of complexity to the model. Unlike the other supply solutions included in the model, district heating is an energy carrier system which itself can be supplied by a variety of generation technologies. The following assumptions and rules have therefore been applied to the DH modules within the model:

- The model assumes that DH will always be the means of delivering medium scale CHP, secondary heat, geothermal heat, and energy from waste heat;
- for indicative supply costs the model assumes that heat customers pay a 10% discount[11] over average heat prices as an incentive to switch from an in-unit supply solution.
- the MAC for DH networks in the model is calculated based on a weighted average of active systems. In domestic and non-domestic MAC modules, costs only for heat distribution and consumer interface are included (i.e. the pipework and equipment such as a meter that connects the transmission main to the property, but not including radiators within the property); heat generation plant and transmission costs are accounted for in the main DH module.

DH economic performance varies widely from scheme to scheme, and economic viability can be dependent on the nature of existing and new-build stock connected. For this modelling exercise, however, we have applied appropriate average performance figures based on published data and Arup's own experience in delivering DH networks in the UK.

3.5 Technologies and interventions considered in the model

The HPSM investigates a suite of existing technologies and measures that are potentially suitable for delivering a decarbonised heat sector for Scotland. These are grouped into heat demand reduction measures for retrofit (fabric insulation etc.) and heat supply technologies (boilers etc.). The tables below detail the main technology classes considered and briefly highlight the benefits and challenges associated with them, where appropriate.

[11] Based on Arup experience. Note again that heat supply prices and pricing formulae are prone to variation on a scheme-to-scheme basis. To provide an updated figure in future, primary research may need to be carried out if such data are not available publically or through other means.

Table 3. Summary of domestic demand reduction retrofit measure options in the HPSM

Measure	Description
Cavity wall insulation	Insulate cavity walls to reduce heat losses to the outside air. Generally a straightforward process but certain cavity walls may not be easily treatable.
Solid wall insulation	Apply internal or external cladding to old-fashioned solid walls, bringing thermal performance near to that of modern retrofit insulated cavity walls. The market is still maturing for this technology, and installer experience is growing.
Loft insulation	Lay insulation in loft cavities to prevent heat losses through the roof. Fast, straightforward, and can often be done as a "DIY" job.
Super / triple glazing	High efficiency glazing significantly reduces the radiant and conductive heat losses from windows. Potentially quite an expensive technology.
Draft proofing	Ventilation heat losses can be very significant; sealing air gaps can be a simple way to deliver savings, but certain homes may prove more challenging than others.
Floor insulation	Heat losses through certain types of flooring to the ground can be very significant. Floor insulation is similar in principle to loft insulation, although installation is potentially more involved.
Reduction of thermal bridging	Thermal bridges occur where conductive (to heat) fabric elements provide a bridge across insulated elements resulting in heat loss. Such bridges are not always easy to identify and may be cost-prohibitive to rectify.

In the case of the non-domestic fabric retrofit, improvement measures are limited in the HPSM to the improvement of insulating properties of walls, roofs, infiltration (ventilation) and glazing.

Additional improvement options may need to be added to the model and scenarios in the future to account of the wider range of demand reduction measures which become available. That said, those identified above generally show the highest potential for demand reduction, hence their prioritisation.

Table 4. Summary of heat supply technology options in the HPSM, benefits and challenges

Technology	Benefits	Challenges
Gas boilers	Modern condensing boilers burn natural gas highly efficiently	Incremental efficiency improvements aside, this technology cannot be zero carbon (unless fed by bio / syn-gas)
Resistive (electric) heating	Conventional resistive heating, such as bar or storage heaters can deliver low or zero carbon heat to the extent that electricity supply is decarbonised.	Not the most efficient means of electrical heat delivery. Extensive use could lead to significant additional demands on electrical infrastructure and requirement for additional generation capacity, for which there would be a cost that is not accounted for in this model.
Solar water heating	Potential to provide a significant portion of a household's hot water demands.	Dependent on available roof space / surface area. Not as effective in Scotland as in more southern latitudes; greater areas required.

Technology	Benefits	Challenges
District heating	A "technology agnostic" means of delivering heat that can be powered by any one of the below technologies.	Infrastructure can be expensive to deliver, and is normally better suited to built-up areas with high heat demand density.
Gas-fired combined heat and power (CHP)	Can be a more efficient use of fossil fuels. Produces relatively high temperature heat that is compatible with existing central heating systems.	Not a zero-carbon technology (though could be if supplied by bio-fuels). Potentially has a role in the mid-term to enable delivery of district heating networks that later switch to zero-carbon heat sources.
Micro-CHP	Small scale CHP technologies that can be fed on fossil fuels to provide heat and electricity efficiently, potentially alleviating electricity supply constraints.	These technologies are for the most part not yet commercially mature. They are fed by fossil fuels (although Stirling engines could operate with an external biomass source); they struggle to compete in carbon terms with a fully decarbonised electricity grid.
Heat pumps	If powered by a low-carbon electricity grid (assuming decarbonisation of Britain's national grid), this efficient heat delivery technology can be a core low carbon heat technology. Can potentially be used to upgrade low-grade industrial heat for domestic uses.	Colder temperatures in parts of Scotland can significantly reduce performance, as efficiency is largely dictated by the heat source (external) and sink (internal) temperature differential, particularly in the case of air-source heat pumps. Wholesale shifting to heat pumps, particularly with reduced efficiencies, could put additional strain on electrical transmission infrastructure, and will require more electrical generation, for which there would be a cost that is not accounted for in this model. Central heating systems would often require new low-temperature (i.e. large surface area) radiators, potentially limiting uptake in existing buildings.
Biomass boilers and biomass CHP	Near zero-carbon heat supply technology. Compatible with existing central heating systems (although additional space for larger boiler plant and fuel store required).	Perceived air quality issues. Supply chain and absolute fuel availability issues. Perceived and actual trade-offs between use of arable land for energy vs. food production.
Geothermal	Uses freely available heat in the ground (directly or indirectly) to produce low-carbon heat, potentially feeding district heating networks.	Locations where technology can be deployed are limited by the availability of appropriate subterranean formations.
Capture of excess (waste) heat	Heat sources include power stations, large scale industry, data centres, rail transport tunnels, sewage pipes etc. A wide range of technologies can capture low grade (i.e. low temperature – circa 20°C - 40°C) heat and provide it for space heating or for power generation. Potential technologies include heat pumps, Stirling engines, organic Rankine cycles, etc.	Heat captured needs to find a local use to be useable. Potential opportunities should be identified in the Scotland heat map. Once complete further research requirements can be identified on the extent of "excess" heat available and nearby demand and if there are appropriate applications to take advantage of this.

4 Data Sources

This section provides an overview of the primary data sources used to develop the 2010 baseline, and those that build up the technology characteristics dataset held within the HPSM. Information is also given regarding future projections and roadmaps that inform thinking. Where appropriate, practical, and permissible (taking account of data sharing agreements in place for certain datasets), further detail is provided in Appendix A. It should be noted that all data issued to Arup containing building-level information has been aggregated to prevent potential identification of individuals and organisations.

4.1 Baseline data

The baseline year is taken to be 2010 (see Section 7 for further detail). The heat, energy, and emissions baseline is broken down into Domestic, Non-domestic, and Industrial sectors.

4.1.1 Domestic data sources

A profile of Urban, Rural On-Grid, and Rural Off-Grid heat demands in 2010 is calculated based on the following key data sources:

- The Scottish House Condition Survey[12] (SHCS), in consultation with the Scottish Government's Housing team. The SHCS is used to build up a statistically representative database on the physical condition of Scotland's homes.
- DEMScot, which is a publically available model. The domestic database within DEMScot was adapted to match the format of the housing stock model previously developed in Arup's work for the Green Construction Board[13]. The database was compiled in 2006, with significant growth in uptake of energy efficiency measures recorded since[14]. The data were therefore adjusted for 2011 to take these improvements into account, by using information provided in the SHCS.
- DECC sub-regional energy consumption statistics 2013 release for domestic consumption. This annual publication is used to calibrate the thermal model in the HPSM, based on the consumption of non-electric heat energy only (electricity for heating is not disaggregated from other electrical use in the dataset).
- Scottish Greenhouse Gas Inventory (GHGI) covering domestic sector emissions by source, 2010. This was also used as a check to ensure correct calibration of the thermal model forming the baseline.

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[12] http://www.scotland.gov.uk/Topics/Statistics/SHCS
[13] http://www.greenconstructionboard.org/index.php/resources/routemap
[14] http://www.scotland.gov.uk/Topics/Built-Environment/Housing/supply-demand/chma/marketcontextmaterials/DEMSCOTversion2

4.1.2 Non-domestic data sources

A profile of Urban, Rural On-Grid, and Rural Off-Grid heat demands in 2010 is calculated based on the following key data sources. Until the Scottish Government's Scotland Heat Map[15] project is complete in early 2014, there exists no comprehensive, publically available dataset on heat demand within the non-domestic sector. Once heat mapping is complete, the baseline can be updated appropriately. The following data sources were used to produce an understanding of the sector that fits as closely as possible with observed data.

- GIS-based mapped resources: Scotland's 2007 national heat map, 2012/13 pilot heat maps provided by Dundee, Fife, Highland, and Perth & Kinross. These recent heat map geographic datasets were used as proxies for the main heat "geographies". These were scaled up across the whole of Scotland, using regional Gross Value Added (GVA) statistics as a proxy for non-domestic demand.
- Scottish public sector procurement data (confidential), which provided gas and electricity consumption for 2010 – 2012. Data was provided by the Scottish Government covering consumption of gas and electricity across central and local government agencies, educational bodies, and the health service. Note electricity consumption is not disaggregated by demand type.
- DECC's Energy Consumption in the UK (ECUK) publication, September 2013, covering 2010 service sector heat demand by fuel type and end use. This UK-level publication was used to derive an indication of the fuel split for the non-public sector non-domestic building stock. It also allowed for an estimate of the proportion of public sector electricity consumption devoted to heating, and the split in demands for gas (catering, DHW and space heating).
- Scottish GHGI, providing Public and Institutional / Commercial sector emissions by source, 2010. Used to calibrate the demand model such that direct emissions by source are consistent with the overall emissions account.

4.1.3 Industrial data sources

Postcodes of industrial sites held in the SEPA SPRI database were cross-checked with HPSM heat geography postcodes. The majority (98%) of sites fall within the "Urban" geography. Accordingly, Industrial heat is presented as a single emissions category.

- Scottish GHGI, which provides emissions from industry by source. Only fuel combustion-derived emissions were considered (not direct emissions from industrial processes).
- DECC ECUK, September 2013, which provides Industrial energy consumption by end use and fuel type, 2010. The heat demand and fuel-use profiles from ECUK were used to produce representative emissions rates from combustion of fuels for the whole of the UK Industrial sector. These were then calibrated with the Scottish GHGI data and converted back to fuel demands;

[15] http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/Heat/HeatMap

assumptions regarding technology and process efficiency allowed heat demands to be estimated.

- DECC sub-regional energy consumption statistics, 2013 release, which shows Industrial and Commercial fuel consumption used in conjunction with Non-domestic modelled figures for fuel consumption allowed for cross-checking of calculations.
- SEPA Scottish Pollution Release Index[16], SPRI.

The resolution of published data on Scottish industrial heat demand is far more coarse than for the other two sectors. The datasets described above only provide consumption and emissions information at the highest level. The baseline and forward projection model for the sector are therefore necessarily of reduced granularity, and do not allow for detailed investigation of emissions reduction potential.

DECC, as well as international institutions such as the IEA[17] are currently in the process of carrying out research on more detailed abatement potential across energy intensive industries. Detailed investigation of industrial heat demands was not within the scope of this work; further information will come out through the Scotland Heat Map work. Once complete it will be clearer if additional further work is needed.

4.1.4 Additional baseline data

An additional source was the Energy Saving Trust (EST) Renewable Heat Database for Scotland. The EST maintains this database to assist the Scottish Government in monitoring its progress towards its renewable heat target for 2020. Information contained in the Excel database, as published in a June 2013 report[18], allowed the HPSM to be populated with baseline values for renewable heat provision by technology, and the existing penetration of district heating.

4.2 Technology data

This section provides an overview of the data sources used to inform the technology characteristics database that underpins the 2010 baseline, as well as the uptake model and energy demand projection calculations to 2050.

A key requirement for this work was that data on technology capital costs, maintenance, efficiencies, lifetimes and projected rates be at a national scale, to fit with the model's level of granularity and wide reach. As such, technology data from individual suppliers or narrow studies into single technologies, or un-verifiable data is not appropriate and was excluded at this stage[19]. Arup was able to draw on the wider research of a number of studies carried out to inform the UK-level policy context, as described in the following subsection.

[16] http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx
[17] http://www.iea.org/roadmaps/
[18] http://www.energysavingtrust.org.uk/scotland/Take-action/Get-business-funding/Renewable-Heat-in-Scotland-2012
[19] At a future date it may be appropriate to carry out a Scotland-specific review of technology costs and performance; after which the HPSM can be updated.

4.2.1 Technology characteristics

The following studies informed the technology characteristics dataset compiled for the HPSM. Appendix A details further which source informed which data.

- DECC: AEA Technology & NERA Consulting, July 2009. The UK Supply Curve for Renewable Heat.
- DECC: Pöyry & Faber Maunsell AECOM, April 2009. The Potential and Costs of District Heating Networks.
- DCLG, July 2011, Zero carbon non-domestic buildings: Phase 3 final report
- DECC 2050 Pathways Calculator technology costs and performance, updated following call for evidence in 2011.
- Delta-EE, September 2012. 2050 Pathways for Domestic Heat.
- DECC: Sweett, February 2013. Research on the costs and performance of heating and cooling technologies.
- Energy Saving Trust data on renewable installations in Scotland; the main source of Scotland specific data, holding cost and capacity data on over 1000 installations. This was provided following the early stakeholder workshop in October.

4.2.2 Resource and technology maximum potential

The following sources were used to inform assumptions around the maximum uptake potentials of various technologies. Further detail can be found in Appendix B.

- Ramboll, July 2013. London's Zero Carbon Energy Resource; Secondary Heat; used as a proxy for secondary heat potential within Urban areas in Scotland.
- AECOM, August 2013, Study into the Potential for Geothermal Energy in Scotland: Volume 1 and Volume 2.
- AEA Technology, September 2011, A Study into the Recovery of Heat from Power Generation in Scotland.
- Forestry Commission, 2011. 25-year forecast of softwood timber availability. Covers availability from publicly and privately owned land in Scotland and the UK.
- High-level estimates provided to Arup by Forth Energy on biomass import capacity of existing Scottish port facilities.

For the domestic and non-domestic sectors, the HPSM makes estimates about the potential maximum penetration of technologies down to the level of heat geography and existing or new-build stock. For instance, the maximum potential for ground source heat pumps in existing domestic urban stock is limited to buildings that have a suitably sized garden. The following sources provided the basis for these estimates:

- High-level calculations performed by the Energy Saving Trust for Arup on the Home Analytics database.

- Scottish Housing Condition Survey; used to estimate the proportions of stock in each geography with certain fabric characteristics (e.g. unfilled cavity walls) conducive to retrofit, or for application of novel heat supply technologies.

4.3 Projections and road maps

As discussed above, the industrial sector in particular is currently not well characterised at a national level. IEA studies have informed the Scottish Industrial sector's future profile, as well as scenario inputs defined in DECC's 2050 Pathways Calculator in 2011.

The following IEA roadmaps[20] represent useful reading around the subject: Carbon Capture and Storage in Industrial Applications; Cement; Chemical Industry via Catalytic Processes.

4.4 Exogenous Drivers

Four key exogenous drivers impact the HPSM:

- climate projections to 2050, specifically average seasonal (spring, summer, autumn and winter) external air temperatures;
- the grid decarbonisation trajectory assumed;
- projections of fuel price; and
- population, housing stock and non-domestic floor space growth projections.

These variables affect the scenarios in the same direction, but with differing levels of impact. Notwithstanding, they can in some cases have a profound effect on the actual decarbonisation progress shown in each scenario.

The base sources for these key external drivers is described below.

- Climate projections: UKCP projections published by DEFRA. Absolute future climate values calculated by combining baseline climatology with UKCP09[21] projections of future climate. The default trajectory is the High Global Emissions trajectory.
- Grid decarbonisation: (central) DECC Updated Energy Projections (UEP), are used to calculate the average annual grid GHG intensity on a consumption basis to 2030[22]. Following this, the average rate of annual decline over the preceding five years is projected forwards. This methodology was previously

[20] http://www.iea.org/roadmaps/
[21] http://ukclimateprojections.defra.gov.uk/
[22] For calculating the emissions from electricity consumed in Scotland, the average grid intensity of the GB system is used as Scotland is part of an integrated GB grid. Dispatch decisions by generators impact upon each other in complex and competing ways. The GB system balances supply and demand by utilising the full range of generating assets across the whole system. Therefore, using only emissions from Scottish generators would not reflect the real per-unit emissions of Scottish electricity consumers. For calculating the emissions from electricity generated in Scotland, Scottish annual generation figures from DECC are used, and information from the GHGI and SPRI, which is the basis for the decarbonisation target.

validated by DECC representatives during work on the Green Construction Board's Low Carbon Routemap for the UK Built Environment.

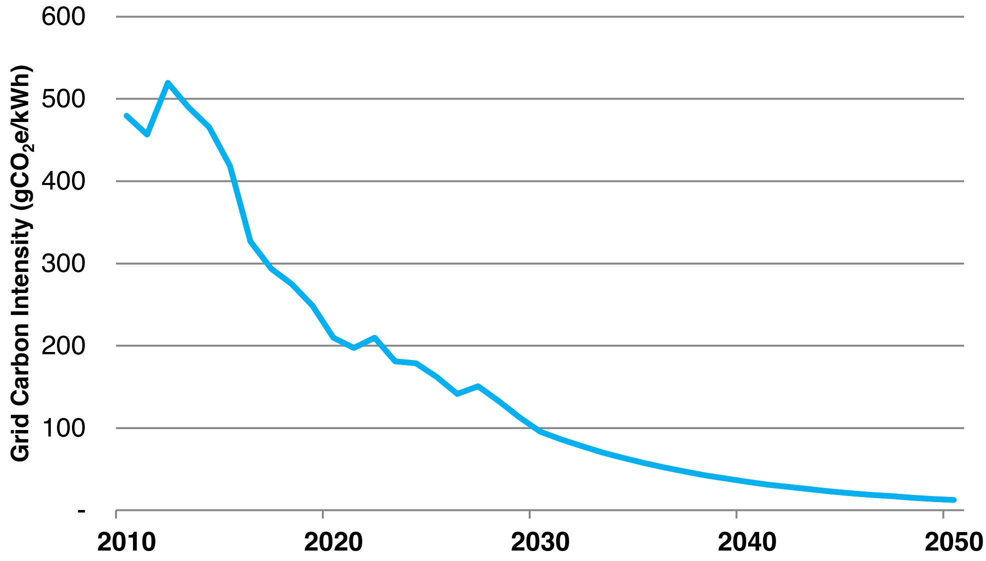

Figure 4. Assumed electrical grid decarbonisation trajectory

- Fuel price projections: where available, DECC fuel price projections as given in UEP are used up to 2030, and then projected forwards. Elsewhere DECC Quarterly Energy Price statistics are used to link products (such as residential burning oil) to wholesale indices. Key prices are indicated in Figure 5 below; further detail is presented in Appendix B.
- Population and housing stock projections: published Scottish Government projections on population numbers and growth in housing stock by local authority are split by geography (based on the broad geography of each authority).

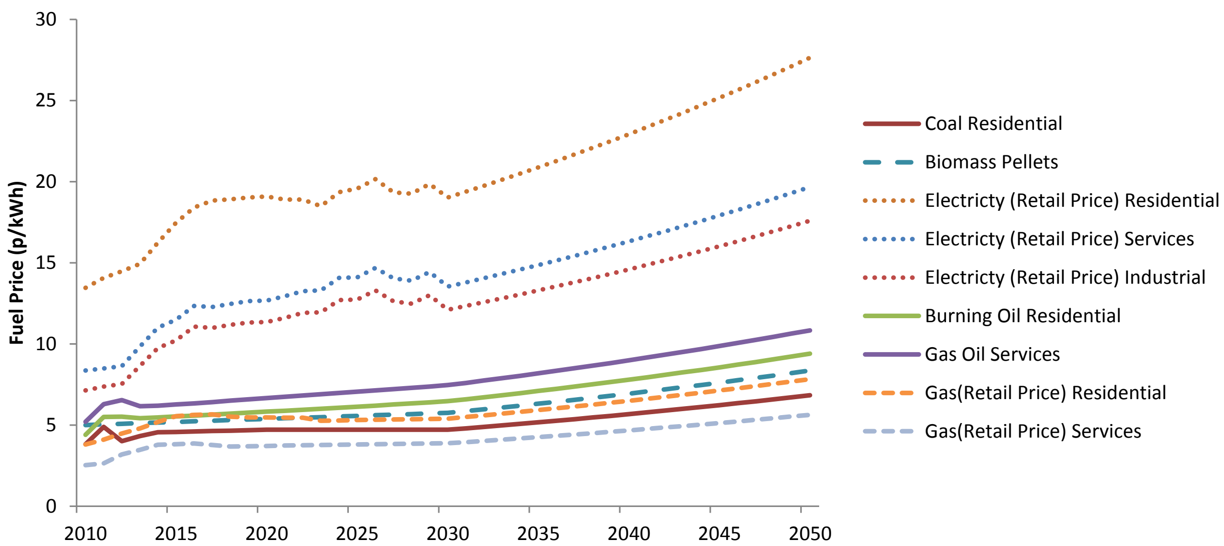

Figure 5: Fuel price projections used in the HPSM model

5 Model Strengths and Limitations

5.1 Data availability

The model is calibrated such that for 2010 it reflects Scotland's heat emissions account as closely as possible. However, uncertainty as to the actual makeup of the non-domestic and industrial stocks in particular means that the effect of applying the measures considered could in reality lead to different (better or worse) outturn performance.

The accuracy of the HPSM model, particularly in the first decade, can only be improved with better source data; the Scotland Heat Map programme will be the first step to providing the necessary consistent evidence base.

As indicated in Section 4.2, the HPSM is a nationwide model that is designed for contemplation of broad, sector-level trends and effects of future scenarios. This has necessitated the use of data for, amongst other parameters, technology costs and performance that are similarly broad and as representative as possible.

Where data are lacking or of poor quality, we have attempted to model the gaps to the best degree possible within the constraints of this research. But, as indicated for the industrial and non-domestic sectors, further research and quantification is recommended and in some cases is already in the process of being carried out by other parties.

5.2 Costing

The HPSM presents capital and operational costs through to 2050. These costs are a valuable means for comparing the performance of individual scenarios, but their limitations should be understood. Many of the limitations reflect a practical balance which was struck between sensitivity and complexity:

- Technology price projections are fixed, but are in reality likely to vary in response to demand.
- As described above, the model generalises technology costs; for instance, in the model a heat pump installation in a detached house costs as much as an installation in a terraced house. In reality, costs vary widely between technologies, manufacturers, suppliers and geographies, to name but a few variables.
- Fuel price projections are treated as exogenous, whereas in reality they would be somewhat impacted by technology uptake, particularly for fuels with local or small markets, such as biomass..
- Consumer fuel demand in the model is price-inelastic, being determined only by defined comfort levels in the scenarios.
- Operating costs presented in the HPSM do not necessarily translate to energy bills. How bills vary in the future will depend on policy design and implementation. The model does use nominal subsidies and levies to affect technology choice in the various scenarios.
- Exogenous factors such as industrial productivity or commercial floor space growth largely govern new-build demand; whether there is growth or decline,

these underlying trends are not costed but can lead to significant apparent costs or savings.

- In the case of heat supply technologies, the model considers costs associated with all replacement systems even if they are like-for-like. This means that, in a scenario where there is no change in heat supply mix, costs will still be incurred periodically to 2050 for replacement of existing systems at end of life.
- For domestic and non-domestic new-build construction costs, the model only presents costs relative to a notional baseline. The entire cost of, say, a Passivhaus standard construction is not quantified, only the additional expense associated with improving the building fabric and ventilation performance against a standard regulation-compliant house.
- The cost of decarbonising the United Kingdom's electricity grid is not included in the HPSM. A number of the scenarios rely heavily on grid decarbonisation to achieve low-carbon heat futures. Aside from projected increases in electricity costs, no allowance is made for the electrical infrastructure costs associated with the scenarios. These costs include costs for installing additional renewable and low-carbon generation capacity, and the costs of upgrading, reinforcing and increasing transmission and distribution capacity appropriately.
- Wider social benefits or costs, such as climate change effects or air quality related health issues are not included.
- Costs for offsetting of new-build emissions (where scenario emissions targets are not met) are estimated, but do not cover sources of non-heat regulated emissions (i.e. lighting).

The following cost items are explicitly calculated within the model. In all cases the cost assumptions used can be found in Appendix A.

Capital Costs

- New and replacement Domestic and Non-domestic heating system capital costs (excluding installation).
- Costs of fabric retrofit in Domestic and Non-domestic sectors.
- Costs of fabric in new-build Domestic and Non-domestic stock *additional to baseline costs*. That is, the entire cost of building a house / office is not calculated, only the assumed additional cost of implementing more stringent fabric measures than the baseline.
- Costs of new-build carbon offsets where scenarios mandate "net zero" standards.

Operational Costs

- Costs of Domestic, Non-domestic and Industrial fuel purchase.
- Domestic and Non-domestic maintenance of heat systems.
- Costs of Industrial CCS in scenarios where it is implemented.

5.3 Scenario comparison

The HPSM's strength and of course purpose is its ability to compare national heat scenarios out to 2050 as defined by the user on as even a footing as possible. Due to its structure and resolution it is not appropriate for short or mid-term analysis. The scenarios presented should be evaluated in the context of their governing and exogenous drivers.

6 Scenario driver descriptions

The trajectory of the four modelled scenarios relative to the Reference scenario (described in detail in Section 8.2.2) depends on High or Low levels of drivers reflecting Government Intervention and Uptake. There is a range of possible levels that could be modelled, but this work focusses on discrete High and Low values.

It can be noted that the drivers as defined here would see some level of feedback from each other. For example, high Uptake is unlikely to occur without some degree of Government Intervention. However, the HPSM does not attempt to model such interdependencies.

The below sub-sections provide an overview of the assumptions and inputs that inform these scenario drivers. Further detail on all values assumed is provided in Appendix A.

6.1 Government Intervention

The Low Government Intervention scenario drivers are characterised as follows:

- Consumers choose heat supply technologies based on their levelised net annual cost (NAC) of energy (£/kWh). This is because without Government Intervention to require account to be taken of GHG emissions, consumers are assumed to select the least cost choice.
- The implementation of regulatory provisions for new-builds is somewhat slowed, and "net zero" carbon standards incorporating offsetting payments from new developments are not fully realised until 2030 for both domestic and non-domestic sectors.
- The public sector does not lead by example; existing refurbishment rates for public sector stock remain unchanged from those assumed for 2010.
- No price is placed on industrial GHG emissions, resulting in zero uptake of CCS in applicable industry sectors.
- Capital and operating subsidies such as the RHI and RHPP are not continued beyond their current committed programmes.

The High Government Intervention scenario drivers are characterised as follows:

- Consumers choose heat supply technologies based on their marginal abatement cost (MAC; measured in £/MtCO_2e avoided). This could be through massive public awareness raising campaigns and product labelling and/or through some form of mandate.
- The implementation of stricter building regulations standards follows current timetables. More stringent fabric standards in the new-build sector are mandated sooner than in the Low Government Intervention scenario.
- A "net zero" standard is implemented for new domestic and non-domestic buildings by 2019 for non-domestic, which can be achieved through on- or near-site measures, or through purchasing appropriate offsets.

- The public sector leads by example, with traditionally slow retrofit cycle buildings in Education, Government and Health increasing their retrofit rate by 40% compared to assumed retrofit rates in 2010.
- Capital and operating subsidies continue to be available at their current rates out to 2050. The rates included are presented further in Appendix B.

6.2 Uptake

As indicated in Section 3.2, it is likely that high levels of Uptake would not be realised without some level of Government Action. However, the two sets of drivers operate independently in the model, so results must be interpreted with this in mind.

The Low Uptake scenario drivers are characterised as follows:

- Domestic and non-domestic consumers continue existing trends in consumption; average internal temperatures and hot water consumption increase by 5% each.
- In the non-domestic (non-public) sector, there is no change in existing assumed retrofit rates.
- Consumer selection of heating technologies is geared towards the *status quo*, with incumbent technologies favoured and unconventional and unfamiliar options marginalised.

The High Uptake scenario drivers are characterised as follows:

- Domestic and non-domestic consumers reverse current trends and see a downward path in consumption to 2050; average internal temperatures and hot water consumption decrease by 5% and 10% respectively. Note that a decrease in *average* temperatures does not imply colder homes *per se* (see Section 3.2 for further explanation)
- The non-domestic sector sees a uniform increase in retrofit rates, enabling energy conservation measures to penetrate more rapidly and reduce demand of the existing stock.
- Consumer selection of heating technologies reflects an understanding of the priority assigned to climate change mitigation; low-carbon technologies see significant increases compared to the low acceptance scenario, while fossil-fuel based technologies are given much less influence.

7 The 2010 Baseline

This section describes the 2010 emissions and energy consumption baseline from which all scenarios are compared. The use of a baseline year allows for fair, evidence-based comparison of scenario trajectories, with the historical emissions and fuel consumption figures being largely[23] on record.

2010 was chosen as the baseline year primarily due to relatively good levels of overlap in the available datasets, but it should be noted that other baselines, such as those for total national emissions are normally set to a 1990 baseline. Analysis of the Scotland's Greenhouse Gas Inventory[24] (GHGI) indicates direct (i.e. not electricity related) heat emissions reductions of 19.5% versus 1990 have already been achieved at a national scale up to 2010, so it can be noted that any reductions quoted against a 2010 baseline will be even greater when compared to 1990.

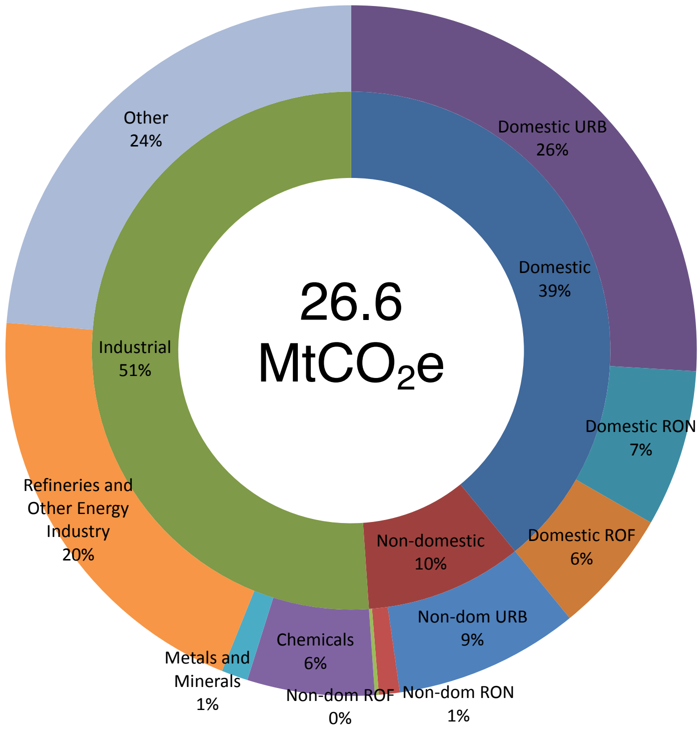

Figure 6: The 2010 Scottish Heat Emissions (traded and non-traded) Baseline.

Notes: URB = Urban, RON = Rural On-Gas Grid, ROF = Rural Off-Gas Grid

As the figure above shows, Scottish heat emissions in 2010 were 26.6 $MtCO_2e$, representing 46.7% of Scotland's total carbon account in that year. This includes traded and non-traded emissions. It should be noted that 2010 was a particularly cold winter, which could have had an effect on total heat emissions performance; a significant peak in residential emissions in particular was recorded in this year.

[23] As discussed previously, some assumptions were necessary in developing this baseline due to data gaps; should these gaps be filled in future the accuracy of the baseline year will only improve.
[24] Scottish Greenhouse Gas Inventory 2010 (http://www.scotland.gov.uk/Publications/2012/07/9583)

Heat in the domestic sector is the dominant source of emissions, but the industrial sector is also a very significant contributor. Emissions arising from buildings in the "Urban" heat geography account for 88% of Scotland's total heat emissions, or 36% if excluding the industrial sector.

The construction of this baseline provides the model with a basis for forward projection and historic comparison. The word "baseline" used in the context of this work should not be confused with the term "business as usual (BAU)", which can have a range of interpretations. The HPSM does not run a BAU scenario to 2050, opting instead to project a "Reference" case of Scotland's performance based on policies existing within RPP2, as described further in Section 8.2.

The tables below indicate the sources used to model this baseline and cross-check the observed, real-world statistics with those output from the model. Direct cross-checking / calibration was only possible for consumption of non-electric fuels; electricity consumption figures for domestic and non-domestic sectors are not disaggregated by use (i.e. heat / non-heat). Overall, modelled total non-electric fuel consumption and direct emissions differ no more than 0.2% and 0.2% from official statistics respectively. At sector-level, the gaps widen slightly, with emissions in the non-domestic sector in particular 13% lower than in the GHGI. Nevertheless, this difference represents only 1.2% of total direct emissions.

Table 5: Baseline model Scottish primary energy (not electricity) and direct emissions for heat comparison with published datasets

Sector	Modelled Non-electric Fuel Consumption, 2010 (TWh)	Non-electric* fuel consumption, DECC regional statistics for 2010[25] (TWh)	Modelled Direct Emissions, 2010 ($MtCO_2e$)	Direct Emissions in GHGI[26], 2010 ($MtCO_2e$)
Domestic	35.14	35.15	7.65	7.98
Non-domestic	7.86	N/A	1.70	1.95
Industrial	41.47	N/A	10.79	10.62
Non-domestic & Industrial Total	49.34	49.37	12.48	12.57
Scotland Total	**84.48**	**84.52**	**20.13**	**20.55**

*Note: figures do not include bioenergy and waste consumption, as it is not disaggregated by sector.

There exists no direct means of verifying the consumption of electricity for heat using published data. Modelled figures for the domestic sector are likely to be close to reality, as they are based on SHCS information, and they are within a plausible range. For the non-domestic and industrial sectors, however, there is less certainty due to the more limited information available, although it can be noted that the public sector non-domestic sector estimates are based on real meter readings.

25 https://www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2010
26 https://www.gov.uk/government/publications/devolved-administration-greenhouse-gas-inventories

Figure 7 below indicates how the emissions baseline compares to the energy baseline for 2010.

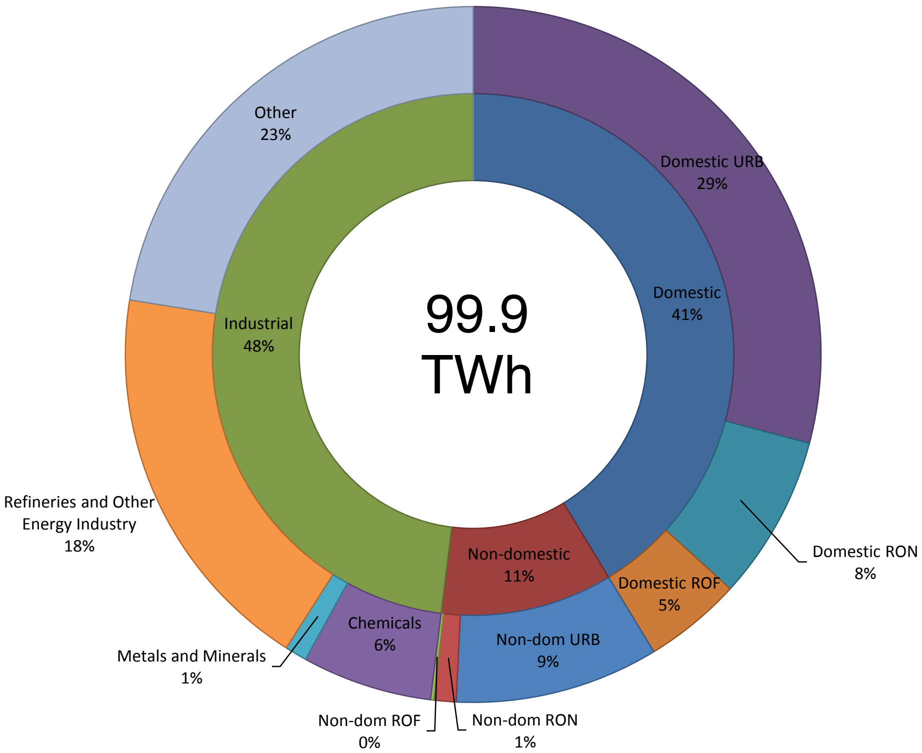

Figure 7. The 2010 Scottish Heat Energy Consumption Baseline. *URB = Urban, RON = Rural On-Gas Grid, ROF = Rural Off-Gas Grid*

7.1 1990 emissions baseline estimate

Heat and energy consumption data of equivalent quality and granularity to that used for 2010 is not currently available for 1990. Nevertheless, an indicative estimate for 1990 baseline emissions can be made based on data in Scotland's GHGI, and a simple set of assumptions around historic energy use patterns.

Direct emissions, i.e. those from on-site combustion have been extracted directly from the GHGI. Indirect emissions, or those arising from the use of electricity for heat, were derived from total electricity emissions given in the GHGI for each sector. ECUK data for Domestic electricity use for heat in 1990 was used for the domestic estimate, while ECUK data for 2010-2012 were used to estimate Non-domestic and Industrial figures.

The implicit assumption in this estimate is, therefore, that Scottish energy consumption for heat in 1990 matched UK profiles in the Domestic sector, and current UK profiles in the Non-domestic and Industrial sectors. The particular aspect of the profiles for which Scottish data is unavailable is the split in electricity consumption for heat uses (which are included in the model) and non-heat uses (which are excluded from the model). We believe the variations between UK and Scottish profiles are modest and therefore the figures provide a reasonably reliable estimate of 1990 and 2010 heat-related GHG emissions.

Figure 8 below presents the 1990 baseline estimate alongside the 2010 modelled value. Estimated emissions of 32.3 $MtCO_2e$ in 1990 have shown a reduction of

17% over the 20-year period to 2010, with the most significant reductions occurring in the Non-domestic and Industrial sectors.

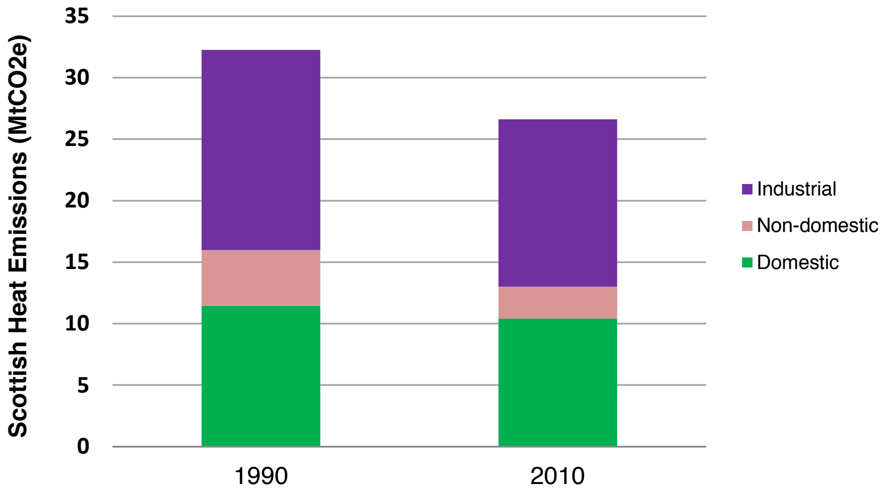

Figure 8. Estimated 1990 GHG emissions baseline compared to modelled 2010 value.

8 Pathway Scenarios

8.1 Overall scenario results and outcome indicators

Five scenarios have been created using the HPSM. The scenarios reflect the Reference case and four alternative scenarios which respectively reflect Low or High levels of Government Intervention and Uptake. The results of the scenario modelling are shown in the two figures below. Both figures reflect identical individual scenario settings; however, the first figure shows these scenarios against a backdrop of electricity grid decarbonisation in line with DECC central projections[27], while the second shows how the scenarios develop without significant grid decarbonisation.

Electrical grid decarbonisation is a key exogenous assumption in this work, and is consistent across all scenarios. Unless stated otherwise, all scenario results presented assume electrical grid decarbonisation in line with DECC projections.

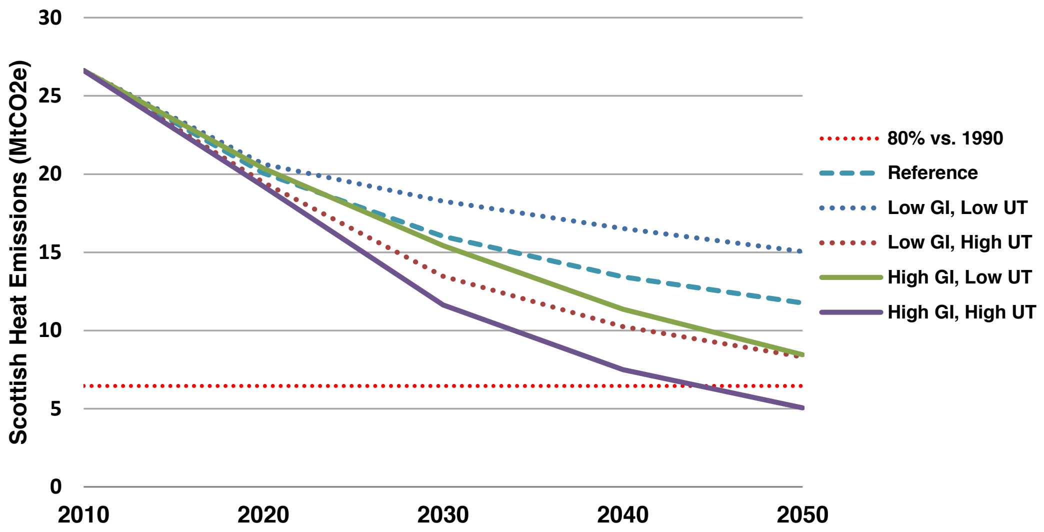

Figure 9. Summary graph of pathway scenarios, including electricity grid decarbonisation. Line for 80% reduction vs. indicative 1990 baseline provided for information purposes.

[27] https://www.gov.uk/government/publications/2012-energy-and-emissions-projections

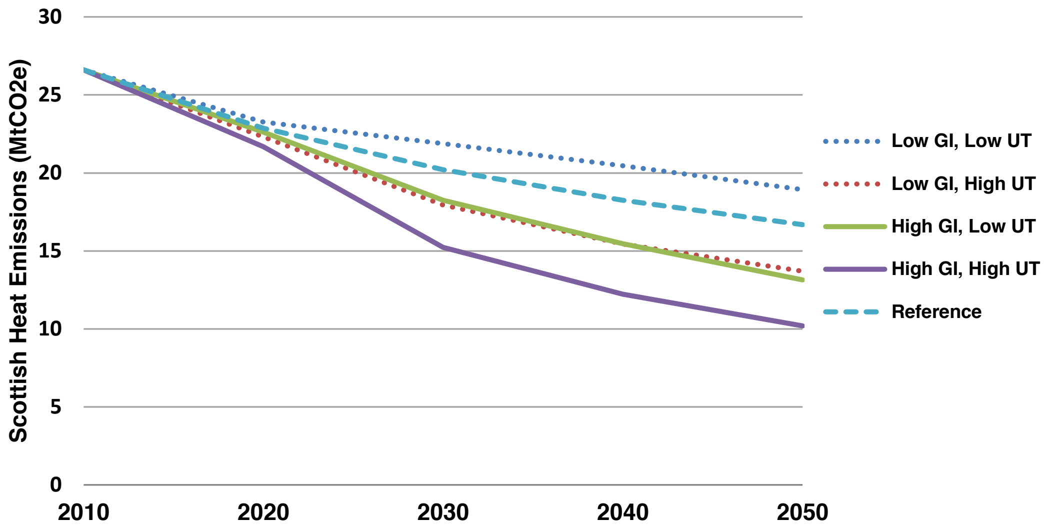

Figure 10. Summary graph of pathway scenarios, with no change in grid carbon intensity from 2010.

The scenario results indicated in Figure 9 include both traded and non-traded emissions, as it is the aim of this work to develop the most complete understanding of Scottish GHG emissions associated with heat. For information, Table 6 below provides total estimated non-traded emissions trajectories for all scenarios.

Table 7 below provides a snapshot summary of the main indicator results from each scenario. This is followed by more detailed discussions of each scenario. At the end of this chapter there are three cross-scenario discussions covering District Heating, household fuel costs and biomass.

Table 6. Non-traded emissions trajectories for all scenarios

Scenario	2010	2020	2030	2040	2050
Low GI, Low UT ($MtCO_2e$)	12.6	11.3	10.6	9.9	9.0
Low GI, High UT ($MtCO_2e$)	12.6	10.6	6.8	5.2	4.4
High GI, Low UT ($MtCO_2e$)	12.6	11.5	8.8	6.1	4.4
High GI, High UT ($MtCO_2e$)	12.6	10.8	5.9	3.7	2.5
Reference ($MtCO_2e$)	12.6	10.9	8.7	7.5	6.6

Table 7. Scenario key outcome indicators

	2010 Value	Reference Scenario	1: Low GI, Low UT	2: Low GI, High UT	3: High GI, Low UT	4: High GI, High UT
GHG change vs. 2010 by 2030 ($MtCO_2e$/yr / % change)	26.6	-10.6 / -40%	-8.4 / -31%	-13.2 / -49%	-11.2 / -42%	-15.0 / -56%
GHG change vs. 2010 by 2050 ($MtCO_2e$/yr / % change)	26.6	-14.9 / -56%	-11.6 / -43%	-18.3 / -69%	-18.2 / -68%	-21.6 / -81%
GHG change vs. 1990 by 2050 ($MtCO_2e$/yr / % change)	-5.6 / -17%	-20.5 / -64%	-17.2 / -53%	-24.0 / -74%	-23.8 / -74%	-27.2 / -84%
Total Energy[28] Consumption by 2050 (TWh/yr)	99.9	70.2	79.8	62.8	72.3	59.7
Heat Demand[29] by 2050 (TWh/yr)	96.1	76.1	83.8	71.7	83.4	71.2
Electricity Consumption for Heat by 2050 (TWh/yr)	13.5	11.3	9.3	12.5	21.3	15.0
Average Annual Electrical Power for Heat (GW)	1.1	1.3	1.1	1.4	2.4	1.7
Additional Peak Electricity Demand[30] vs. 2010 (% change)	N/A	+13%	-13%	+39%	+275%	+98%
% of Renewable Heat[31] by 2020 (target = 11%)	2%	12%	11%	14%	11%	14%
Total cumulative capital cost of measures vs. Reference[32] (%change)	N/A	N/A	-9%	+14%	-11%	+15%
Total cumulative operational costs by 2050 vs. Reference[32] (% change)	N/A	N/A	+6%	-6%	+11%	-7%
Net cumulative costs vs. Reference (% change)	N/A	N/A	+1.7%	+0.2%	+4.4%	-0.4%
Net Abatement Cost[33] vs. Reference (% change)	N/A	N/A	+31%	-19%	-15%	-31%

[28] Consumption of all primary fuels (gas, oil etc.) and electricity across all sectors for heat
[29] Demand for heat as a service, i.e. heat delivered. Note that in all scenarios by 2050 heat demand is greater than energy consumption; this is a result of uptake of solar thermal technologies and heat pumps with coefficients of performance greater than one.
[30] Potential additional generation capacity required during Winter Peaks by 2050, versus 2010
[31] Defined as the delivered renewable heat divided by the total delivered heat from non-electric sources
[32] Includes costs outlined in Section 5.2

8.1.1 Observations from overall scenario comparison

The following observations are made from the results of these pathway scenarios. Note that they depend on particular assumptions (around technology costs, fuel prices, uptake rates etc.), and certain fixed exogenous drivers. In reality, shocks and spikes in the future could lead to rapid changes, the potential for which cannot be readily analysed in these few modelled scenarios.

- As expected, all scenarios show some level of decarbonisation of heat delivery, enabled in particular by the assumed decarbonisation of the electricity grid.
- Compared to an estimated 1990 heat emissions baseline of 32.3 MtCO2e, by 2010 Scotland's emissions from heat had already reduced by some 17%. Despite this, only the High GI, High UT scenario is able to exceed an 80% emissions reduction against a 1990 level.
- Electricity grid decarbonisation is essential to the overall achievement of radical GHG reductions by 2050. Modelling indicates that the greatest reduction achievable, should the grid not fully decarbonise, is 62% vs. 2010, with the Low GI, Low UT scenario only delivering 29% annual GHG savings by 2050. By contrast, the highest reduction achieved in a scenario including grid decarbonisation is 81%. As highlighted previously the cost of electricity grid decarbonisation is not taken into account.
- GI alone (as modelled) enables moderate heat decarbonisation, but can realise an additional 13 percentage point GHG reduction by 2050 when coupled with high UT.
- The Reference scenario, representing a combination of high GI up to 2020, and moderate GI and UT thereafter, closely follows the High GI, Low UT scenario trajectory until 2030.The costs of decarbonising heat are significant, with the greatest emissions reductions scenario requiring around an additional £15bn (15%) of capital spending compared with the Reference scenario. On the other hand, on a net (cumulative capital and operational) cost basis the highest reduction scenario is the also most cost effective, largely as a result of the reductions in energy demand associated with it.
- While there are notable differences between all scenarios for capital and operational costs individually, when combined, cumulative capital and operational costs out to 2050 do not show the same variation, and are very similar. This is largely a result of the semi-optimisation method that the HPSM utilises for technological choice. Despite these similar costs, however, there are markedly different carbon emissions reductions seen across the scenarios, suggesting that managing overall costs is not the primary challenge for Government, but instead that driving demand reduction, stimulating Uptake and overcoming resistance to novel technologies are more important means of achieving a decarbonised heat sector.
- With the exception of the poorly performing Low GI, Low UT scenario, all other scenarios outperform the Reference scenario in terms of net abatement

[33] Defined here as the total cumulative capital and operational costs out to 2050 divided by the annual GHG reduction by 2050 compared to 2010

cost[34]. That is, they can be thought of as more economically efficient scenarios for decarbonising heat.

- In the greatest emissions reductions scenario (High GI, High UT), total electrical demand (TWh) for heat only increases by 32% when compared with the reference scenario, but the High GI, Low UT scenario demands 88% more electricity than the reference scenario, with significant implications for generation, transmission and distribution infrastructure.
- If High GI (as modelled) is not accompanied by high UT, winter peak shock electricity demand could be expected almost to quadruple. This is a result of the scenario conditions leading to higher uptake of inefficient simple electric heating technologies as opposed to more efficient, heat pump-based heating systems.

8.2 Reference Scenario

8.2.1 Basis for Reference scenario

It was agreed with the Steering Group that for this exercise, the firm policies in the Scottish Government's Second Report on Proposals and Policies (RPP2) would be used as the basis for the reference case for the scenarios. That is, before modelling possible alternative futures for heat in Scotland, a scenario which reflected the continuation of existing policies would provide an appropriate basis against which to compare possible futures involving differing levels of Government Intervention and Uptake. This scenario does its best to reflect RPP2 but only within the confines of the modelling framework; the following section describes the assumptions made in developing this scenario.

Specifically, it was agreed that only the firm *policies* in RPP2 would be reflected as best as possible and to avoid confusion with the future HGPS not the RPP2 *proposals*. However, policies which had an expiration date were modelled as not being continued past that date.

We would note here that the RPP2 policies already represent an active level of Government Intervention, meaning that the "Low" and "High" Government Intervention drivers modelled in the other scenarios might better be expressed as "Lower" and "Even Higher".

Nevertheless, a key differentiating assumption between the Reference scenario and the four main scenarios is that consumers are assumed to continue to make decisions on technology choice based on levelised net annual cost (NAC) alone rather than marginal carbon abatement cost (MAC). As such, the Reference scenario's level of Government Intervention is a mix between low and high scenarios.

Regarding future regulation, there are currently no proposals on standards in RPP2 beyond 2015. The low Government Intervention scenario does assume some further tightening of standards beyond 2015; under the Reference scenario we have therefore also assumed a gradual improvement of building regulation standards up to 2025.

[34] See footnote 33

Alongside the well-defined government interventions, we have positioned the Uptake variables for the Reference scenario as reflecting a position part way between the "high" and "low" Uptake scenarios, though biased towards the "low" scenario.

It should again be noted that this scenario does not represent a roadmap for delivering the commitments in RPP2; rather, it is one of a number of possible combinations of factors that could meet the Scottish Government's targets over the next two decades.

8.2.2 Reference Scenario details

The relevant RPP2 policies and milestones are listed below, with a comment on how they have been modelled. Additional details of the scenarios are provided thereafter.

Table 8. How policies and milestones indicated within RPP2 are addressed in the Reference scenario.

Ref	Policy / Milestone	Modelling comment
RPP2 Para 5.2.4 (also see 5.3.4-5	By 2020, every home to have loft and cavity wall insulation, where this is cost-effective and technically feasible, plus simple measures such as draught-proofing and pipe lagging.	The policy is based on a minimum 100mm insulation standard. The HPSM applies a 250mm best practice standard, therefore shows less than 100% achieved by 2020. Draught proofing is included in the model, but pipe lagging and certain other insulation methods have not been included. See Section 3.5 for those retrofit measures considered.
RPP2 Para 5.2.4	By 2020, every home heated with gas central heating to have a highly efficient boiler with appropriate controls.	This is approximately reflected in the model but the model will not show 100% replacement of "old" boilers by 2020, because: The model treats all existing boilers in 2010 as "old" but some "old" boilers are high efficiency condensing boilers. The mix of lower and higher efficiency boilers is reflected in the overall efficiency / carbon intensity of the 2010 "old" boilers. Also, domestic boilers are modelled to have an average 15 year life span, which means that only 66% of existing boilers will be replaced in a given decade.
RPP2 Para 5.2.4	By 2020, at least 100,000 homes to have adopted some form of individual or community renewable heat technology for space and or water heating.	The model indicates an uptake of over 160,000 individual renewable heating technologies (biomass boilers and heat pumps) by 2020 under the Reference scenario.
RPP2 Para 5.5.2 and 6.4.14ff	District heating policies as set out in District Heating Action Plan	DH Action Plan actions are not directly quantifiable in the model. However, the DH uptake assumption rate in the model reflects the priority given to DH by the SG.

Ref	Policy / Milestone	Modelling comment
RPP2 Para 5.5.3ff and 6.4.13	The Renewable Heat Incentive (RHI) in line with the UK Government's policy.	Current (November 2013) RHI levels are reflected in the subsidies for each heat technology. The model assumes no extension of the RHI past its current committed date (2020 for non-domestic, 2021 for domestic)
RPP2 Para 5.5.8 and 6.4.14	District Heating Loan Fund (£5m to RSLs, SMEs and utilities)	Model is too coarse to show the effect of this level of funding.
RPP2 Para 5.5.9	Home Renewables Loans – will be retired when RHI is implemented.	Treated as the same as RHI, as though the RHI commenced in 2010.
RPP2 Para 5.5.10ff and 6.4.18	Heat mapping across Scotland by March 2014	While this is an enabling measure for district heating, low carbon and renewable heat technologies, it is not clear how this can be included in scenario modelling.
RPP2 Para 6.4.14	Renewable Energy Investment Fund. £103m fund to support marine, district heating and community renewable projects.	Model is too coarse to show the effect of this level of funding.
RPP2 Para 6.5.10	Our ambition for heat is that by 2050, Scotland will have a largely decarbonised heat sector with significant progress by 2030. For 2027, this means total estimated abatement of 3 $MtCO_2e$ from the domestic and non-domestic sectors.	This is a forecast and therefore not applicable as a policy to be modelled. However, it provides a reference point for testing of the Reference scenario.

8.2.3 Scenario results

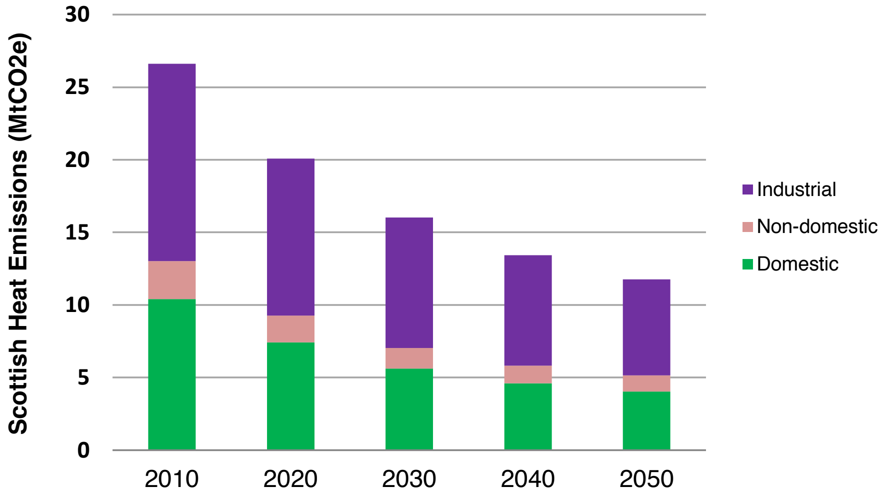

Figure 11. Total Scottish heat emissions: Reference scenario

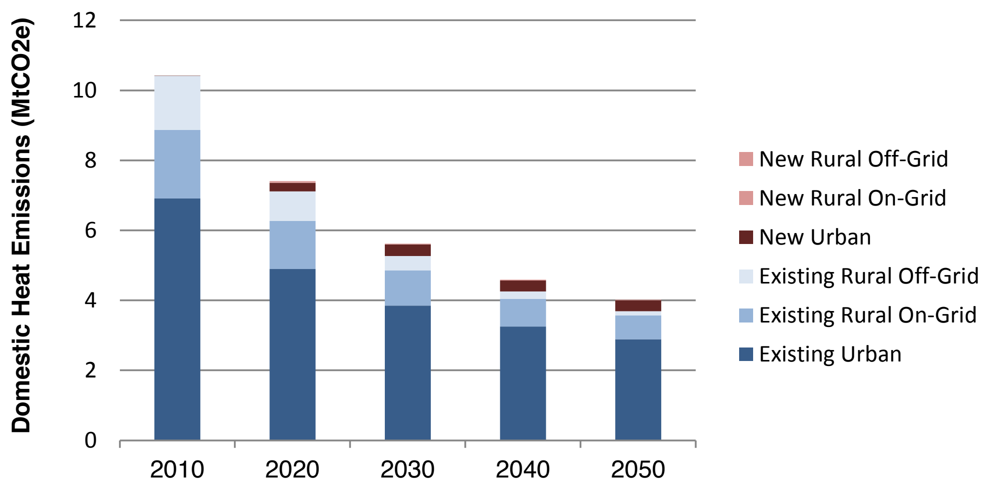

Figure 12. GHG Emissions from heating for the Domestic Sector; Reference scenario

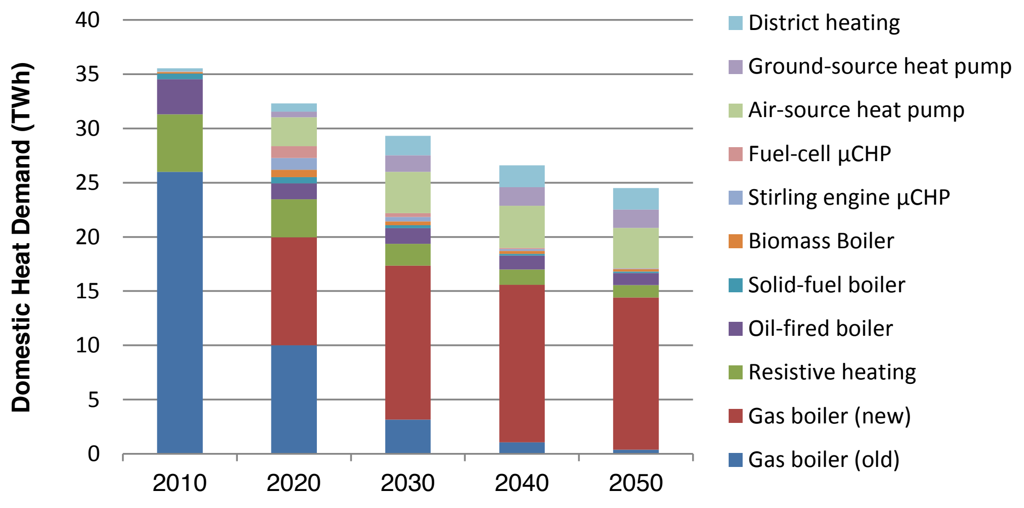

Figure 13. Domestic Heat Demand by supply source; Reference scenario

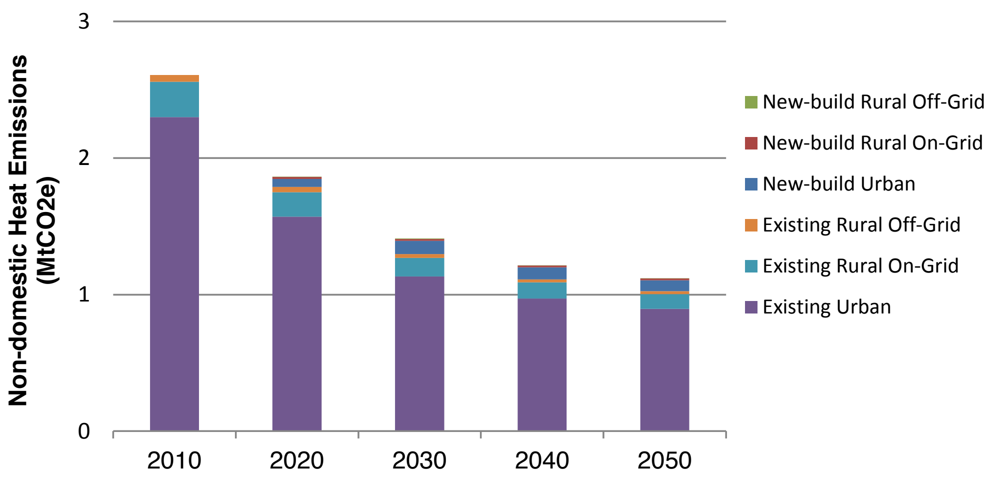

Figure 14. GHG emissions from heating for the Non-domestic sector; Reference scenario

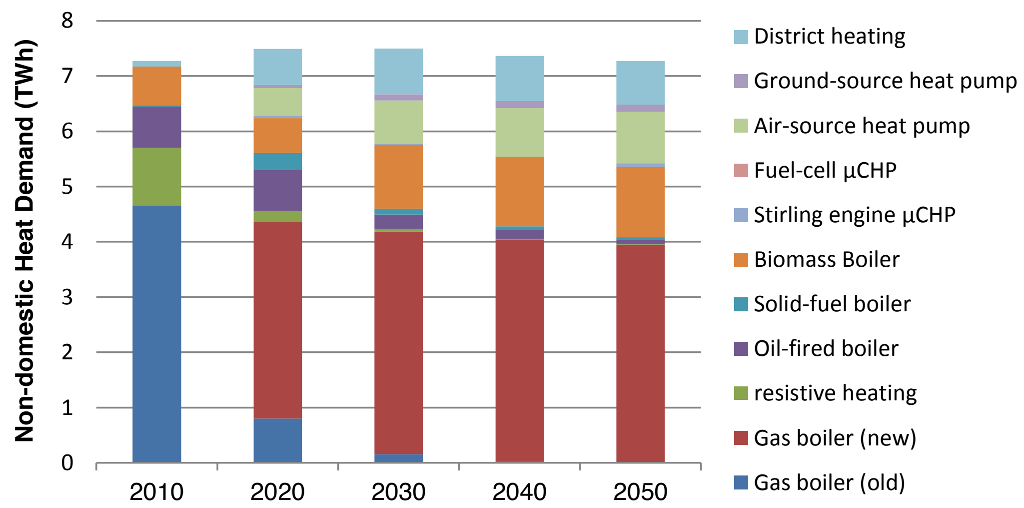

Figure 15. Non-domestic heat demand by supply source; Reference scenario

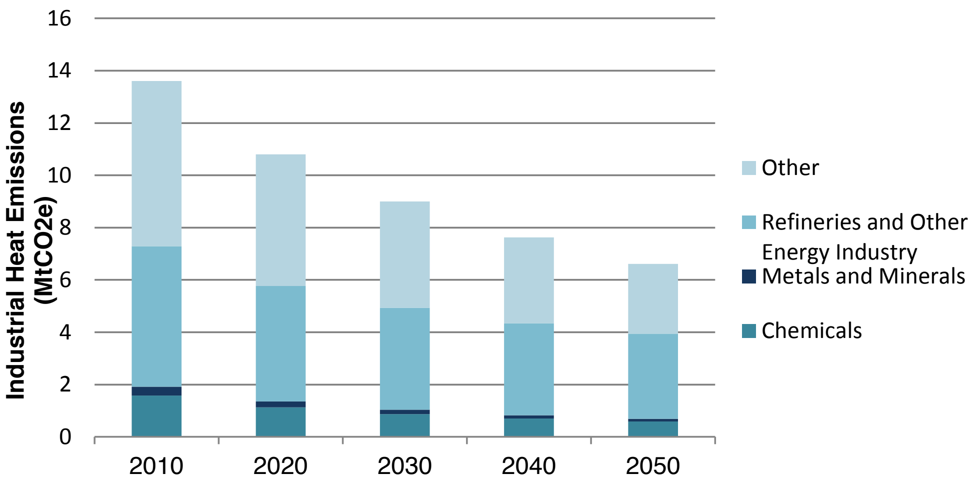

Figure 16. GHG emissions from heating for the Industrial sector; Reference scenario

From a 2010 Scottish heat emissions baseline of 26.6 $MtCO_2e$/yr[35], the Reference scenario sees overall heat emissions fall by 14.9 $MtCO_2e$/yr, or 56%, by 2050. By 2030 significant decarbonisation of heat has already been achieved, with a reduction in heat emissions of 40%. After this point the pace of heat decarbonisation slows somewhat.

Moderate GHG reductions are made across all sectors. The domestic sector in particular reduces its emissions by over 60% through a reduction in overall demand for heat (by about 20%) and a growth in use of modern electric heating (heat pumps) from 2020 onwards. Fabric retrofit of existing domestic and non-domestic buildings is a key enabler for overall emissions reduction; ensuring heat demand does not show a net increase despite new additions to the stock.

In this scenario demand reduction in the domestic sector is mainly driven by retrofit of the existing stock, which reduces thermal losses considerably. New-build standards, whilst not increasing significantly after 2020 as per the scenario definition, are sufficient to limit the additional demand associated with new housing construction. The picture is similar for the non-domestic sector, although heat demand remains relatively constant due to a greater growth in new stock offsetting reductions achieved in the existing stock through retrofit.

Despite a relatively high level of government intervention to 2020, public choices regarding heating are still assumed to be solely cost-focussed. As a result, levelised equipment costs are the primary driver for modelled technology dispatch, rather than carbon abatement costs (MAC).

In the domestic sector, by 2020 reliance on gas boilers, resistive heating (e.g. storage heaters) and oil-fired boilers has reduced. A number of low-carbon technologies come on line in response to price signals that make them competitive with the incumbents. These incentives disappear during 2020-2030, such that the majority of new heat supply (including replacements) by 2030 comes from gas

[35] The build-up of this baseline is described in Section 7, with the data outlined in Section 4.1.

boilers. Heat pumps are then the most significant additional low-carbon heat source, along with district heating, but neither increase their share of supply significantly beyond 2030. Through to 2050 gas boilers continue to supply the majority of domestic heat. The share of micro-CHP technologies erodes due to poor relative financial performance; despite significant cost reductions assumed in the model by 2050, the scenario allows for no further revenues for electricity export from 2030, so these technologies are unable to compete.

The non-domestic sector is more responsive to signals from government than the domestic sector in the first decade. Emissions-intensive solid fuel and resistive (electric) heating are almost entirely substituted by a mix of heat pumps, biomass boilers and district heating. Gas boilers remain a significant energy source, but are mostly modern, condensing types by 2020. Biomass boilers play a far greater role than in the domestic sector. Whilst existing financial mechanisms aid biomass to 2020, it continues to grow thereafter due to the economies of scale when compared to residential systems. The share of gas heating remains relatively unchanged to 2050, with heat pumps and a low-carbon district heating supply making up for reductions in oil-fired and solid fuel boilers. The model indicates a notable spike in the use of solid fuel boilers in 2020 due to apparent cost competitiveness, however this is phased out again by 2040.

Industrial emissions decrease by just over 50% in 2050. This is in part due to efficiency improvements assumed, but in particular for the “other” industrial sector constitutes a shift away from heavy-emitting fuels towards natural gas and electric heating (which benefits from grid decarbonisation) and an increase in biomass use.

8.3 Scenario 1: Low GI, Low UT

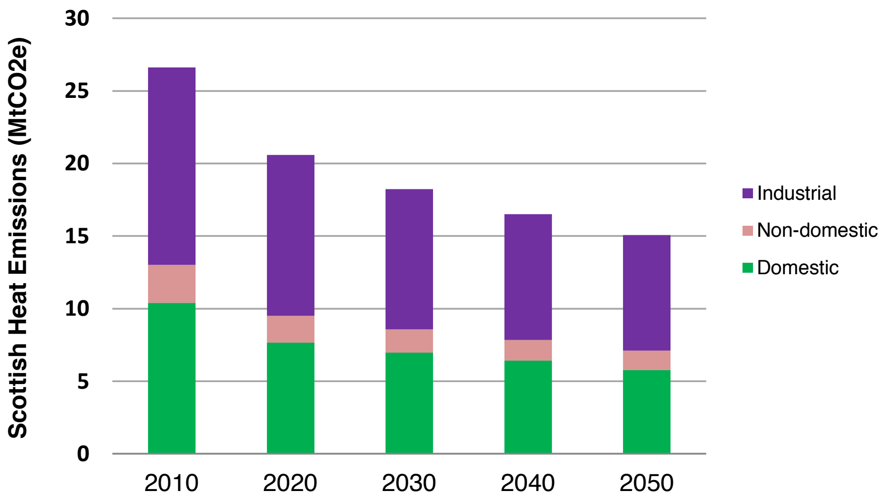

Figure 17. Total Scottish heat emissions; Low Government Intervention, Low Uptake Scenario

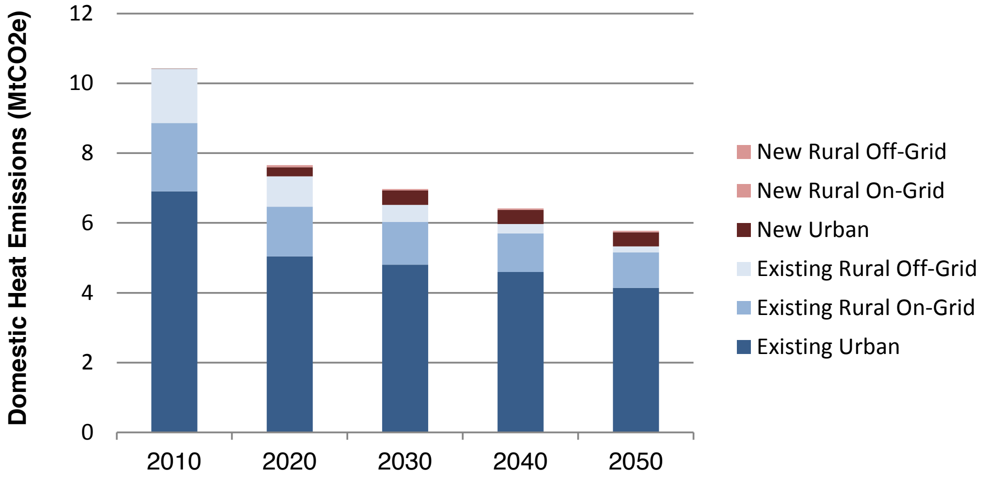

Figure 18. GHG emissions from heating for the Domestic sector; Low Government Intervention, Low Uptake Scenario

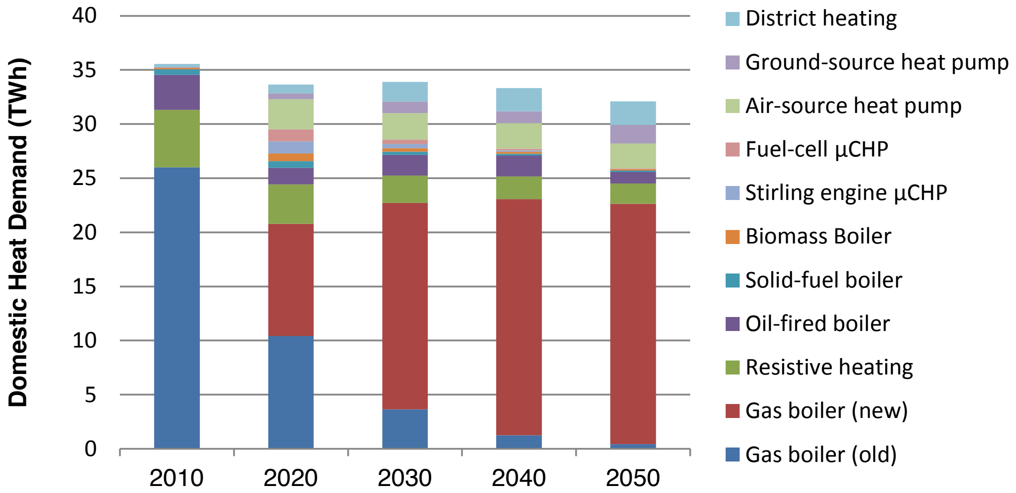

Figure 19. Domestic heat demand by supply type; Low Government Intervention, Low Uptake Scenario

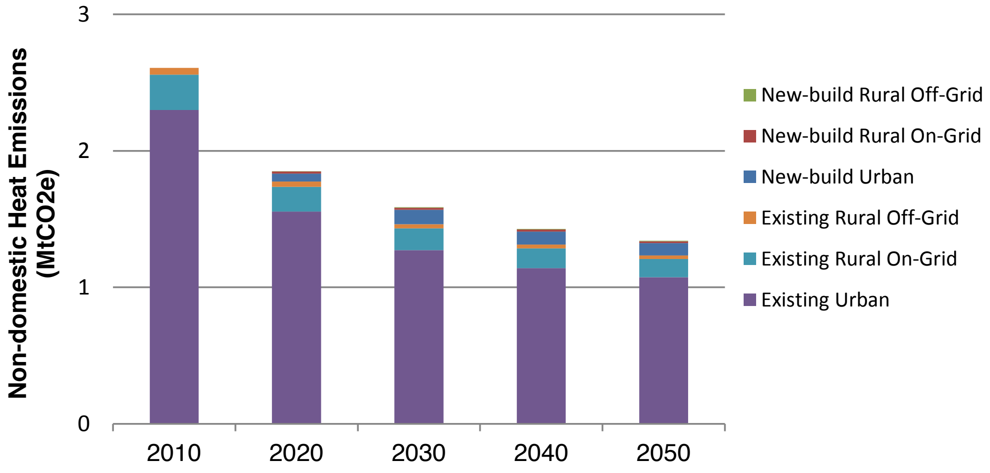

Figure 20: GHG emissions from the Non-domestic sector; Low Government Intervention, Low Uptake Scenario

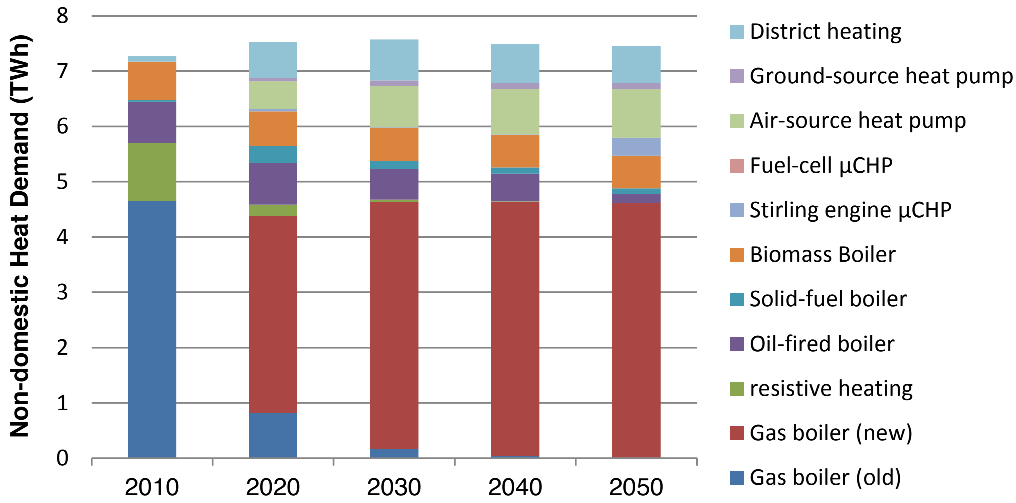

Figure 21. Non-domestic heat demand by supply type; Low Government Intervention, Low Uptake Scenario

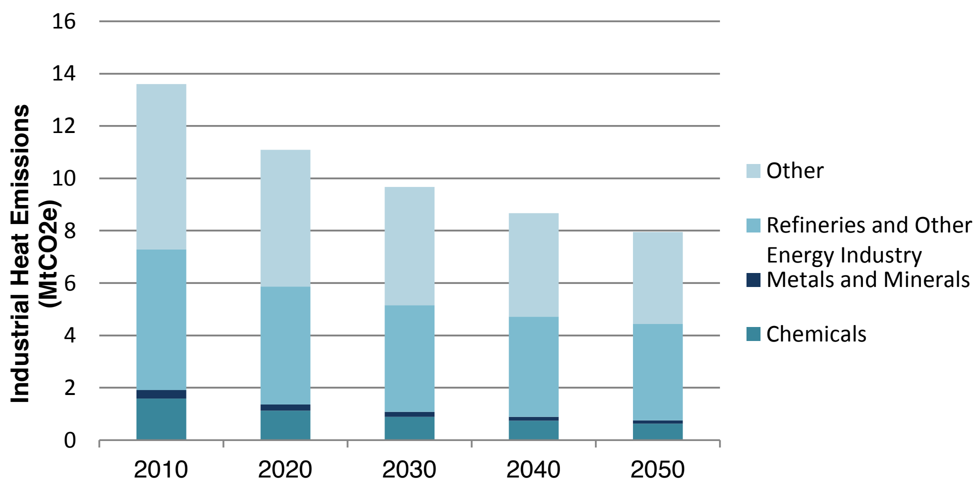

Figure 22. GHG emissions from heating for the Industrial sector; Low Government Intervention, Low Uptake scenario

The Low GI, Low UT scenario's trajectory to 2050 is dominated by consumers' tendency to assess technologies based on their lifetime costs (capital, maintenance and fuel costs) alone and not on their GHG abatement potential, and a desire to continue with existing, familiar means of heat delivery. As a result, a moderate heat emissions reduction of only 11.6 $MtCO_2e$/yr, or 43%, is achieved by 2050, with only 31% achieved by 2030. This is the lowest GHG reduction of any of the scenarios, and is 22% less than that of the Reference scenario.

Within the domestic sector, low public uptake of fabric retrofit measures within the existing stock and limits to implementation of further improvement through regulation leads to residential heat demand remaining essentially constant between 2010 and 2050. Despite relatively poor retrofit progress, implementation is still sufficient to offset gains due to new-build stock.

There is an initial high level of uptake of novel domestic heat-supply technologies to 2020, as a result of existing policies and trends, which displaces old gas boilers in particular. District heating schemes are among the growing alternative solutions during this first decade.

However, over the 2020-2030 decade consumer preferences ignoring abatement potential leads to a rebound in the use of gas heating. Only heat pumps and district heating compete for a share of total supply. Novel technologies, including biomass heating, are excluded almost entirely by 2050. The 45% reduction in annual domestic GHG emissions by 2050 is achieved through the use of more efficient gas boilers and the electricity grid's decarbonisation allowing heat pumps to provide heat with almost zero net emissions.

The non-domestic sector follows similar trends to the domestic sector, with the exception that cost-competitive biomass energy and heat pumps claim a greater share of overall generation by 2050. This enables the sector to reduce its annual emissions by 49% despite relatively constant overall heat demand.

8.4 Scenario 2: Low GI, High UT

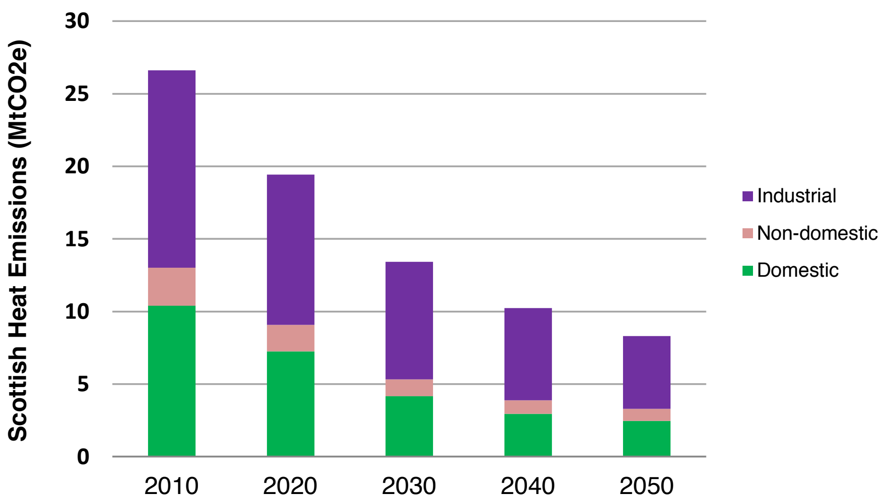

Figure 23. Total Scottish heat emissions; Low Government Intervention, High Uptake scenario.

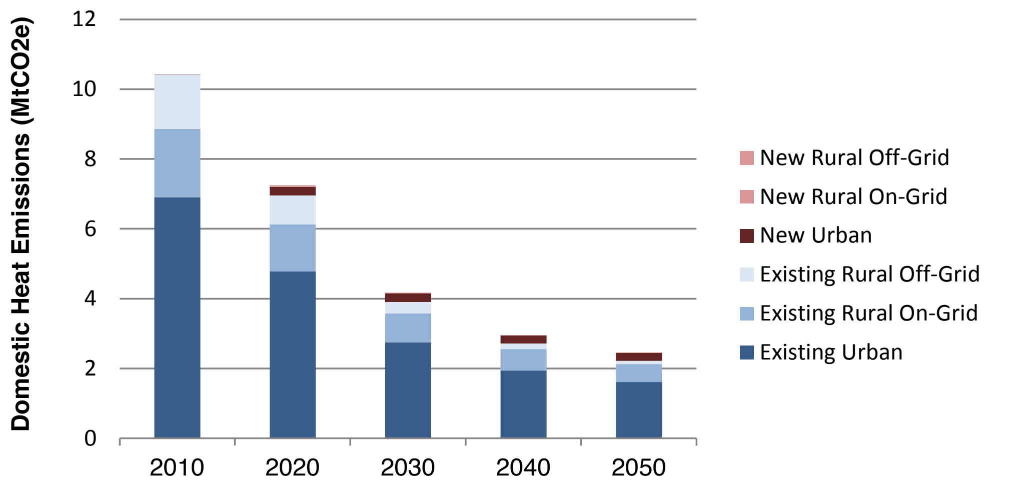

Figure 24. GHG emissions from the Domestic sector; Low Government Intervention, High Uptake scenario.

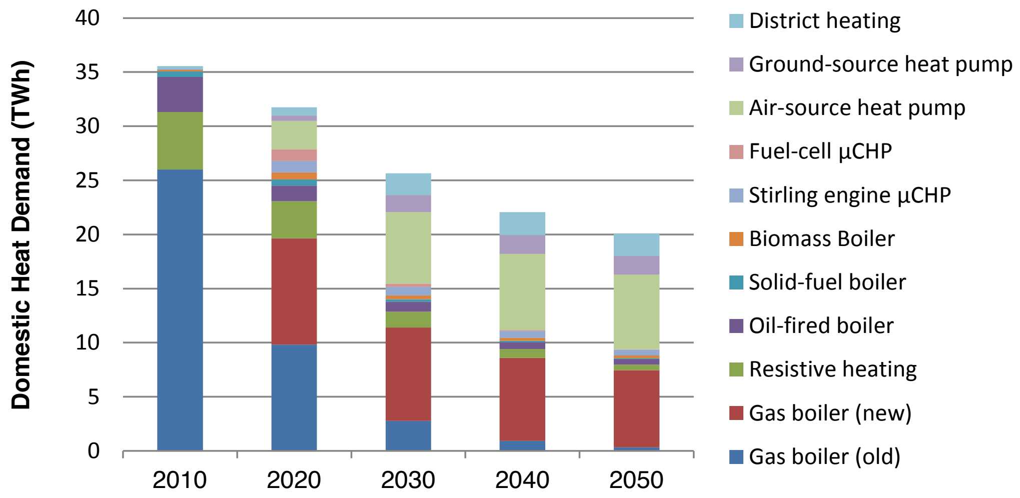

Figure 25. Domestic heat demand by supply type; Low Government Intervention, High Uptake scenario.

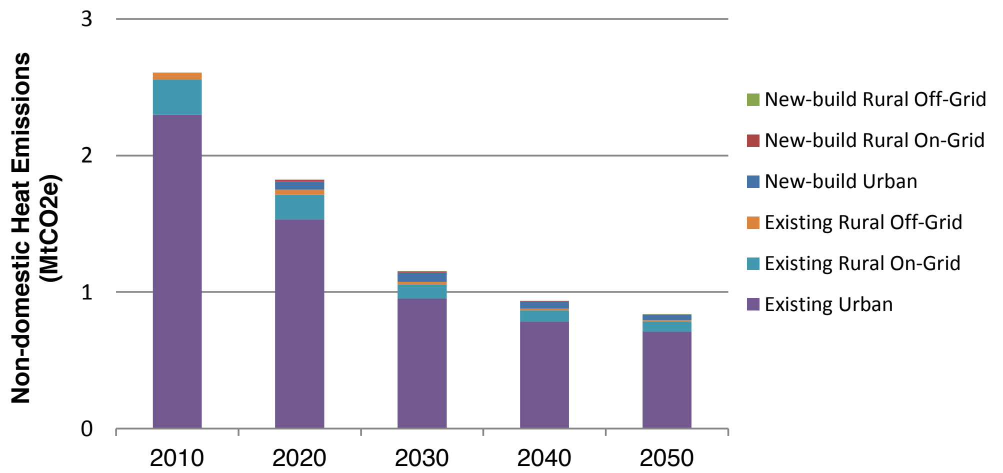

Figure 26. GHG emissions from the Non-domestic sector; Low Government Intervention, High Uptake scenario.

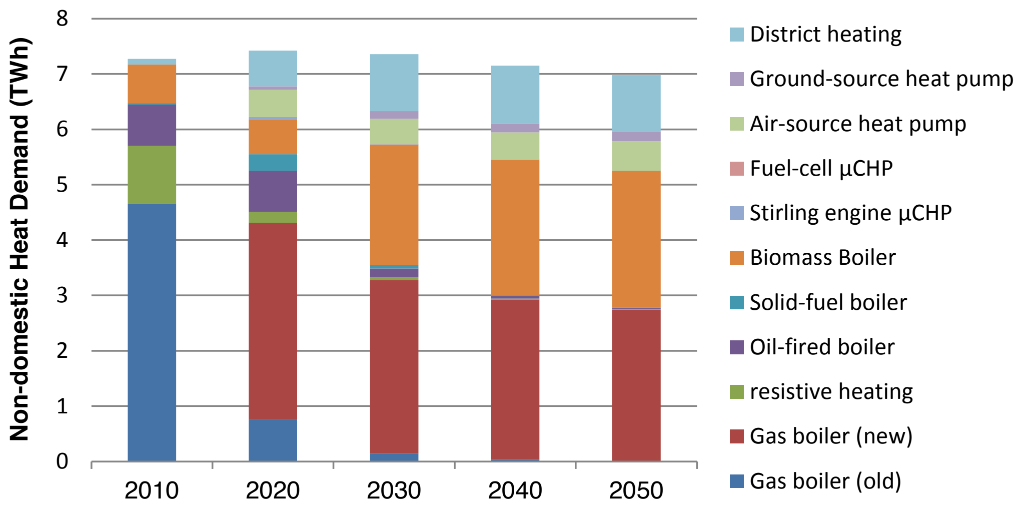

Figure 27. Non-domestic heat demand by supply type; Low Government Intervention, High Uptake scenario.

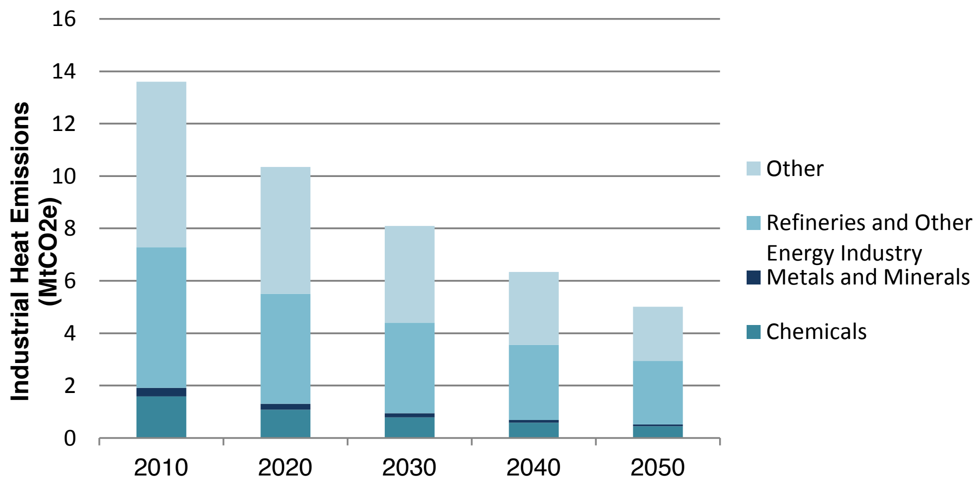

Figure 28. GHG emissions from heating for the Industrial sector; Low Government Intervention, High Uptake scenario

The Low GI, High UT scenario achieves a very similar outcome to the reverse scenario of High GI, Low UT, giving a reduction from 2010 baseline heat emissions of 18.3 $MtCO_2e$/yr by 2050, or 69%. This is an additional 23% reduction over the Reference scenario.

Low levels of government regulatory intervention result in significant deferral of higher building standards for new-builds, but high Uptake drives forward retrofit, such that total heat demand is reduced significantly for the domestic sector. Heat demand reduces for the non-domestic sector, driven mainly by refurbishment of existing commercial building stock. Public buildings, however, do not see significant refurbishment due to Government not leading by example.

Technology choice drivers in this scenario are the same as in the Reference scenario, but due to higher Uptake levels consumers are much more willing to adopt low-carbon heating solutions and energy reduction measures going forwards and act largely independently of reduced government signals.

Consumers in the domestic sector opt increasingly for heat pump solutions after 2020, and district heating plays a growing supply role. The contribution from gas boilers reduces from around 75% in 2010 to around 35% in 2050.

In the non-domestic sector Uptake similarly drives a high uptake of low-carbon technologies, with biomass heating accounting for a very significant fraction (over a third) of total heat generation.

8.5 Scenario 3: High GI, Low UT

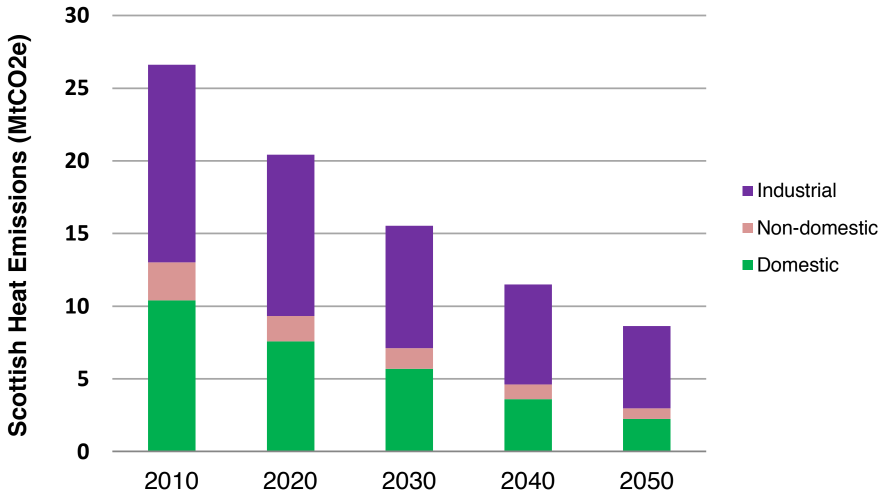

Figure 29. Total Scottish heat emissions; High Government Intervention, Low Uptake scenario.

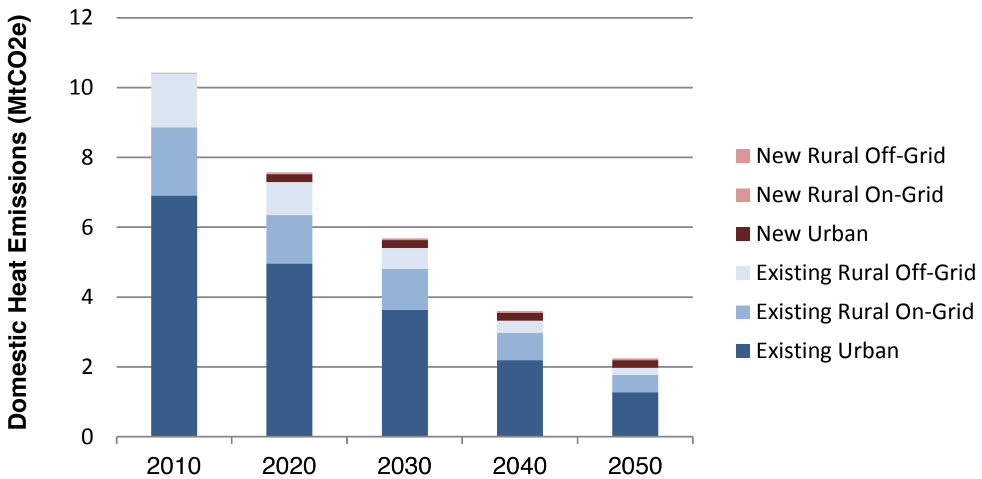

Figure 30. GHG emissions from the Domestic sector; High Government Intervention, Low Uptake scenario.

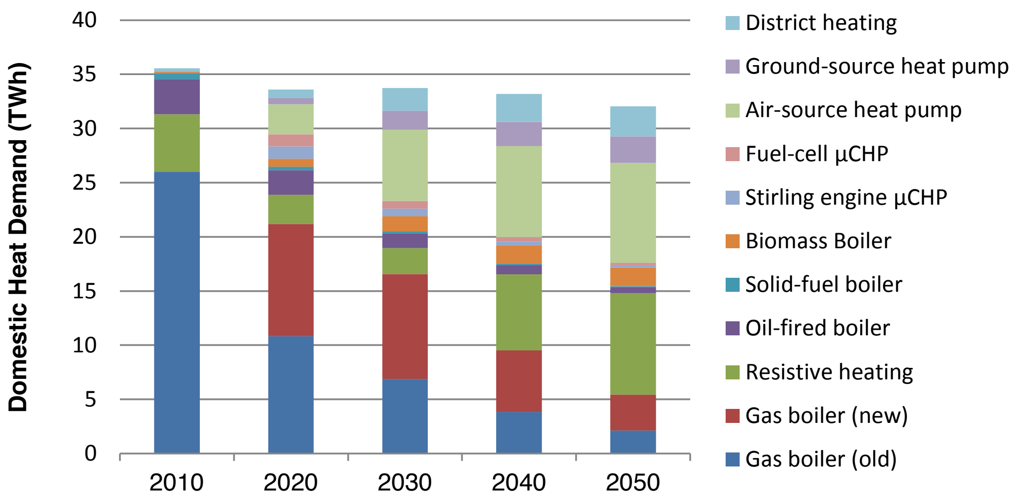

Figure 31. Domestic heat demand by supply type; High Government Intervention, Low Uptake scenario.

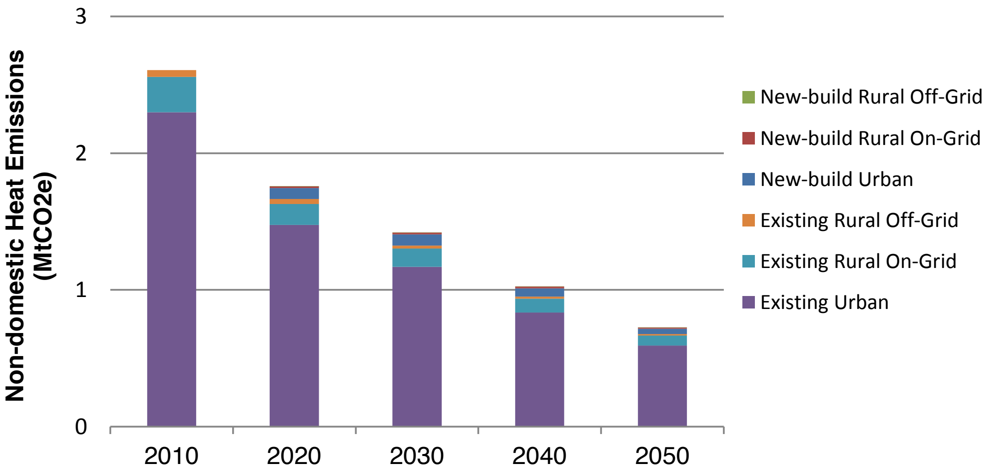

Figure 32. GHG emissions for the Non-domestic sector; High Government Intervention, Low Uptake Scenario.

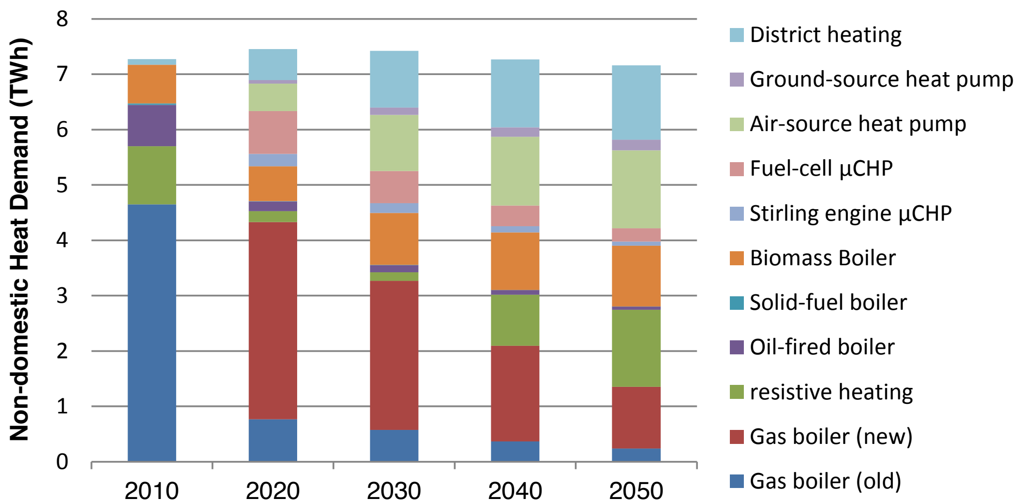

Figure 33. Non-domestic heat demand by supply type; High Government Intervention, Low Uptake Scenario.

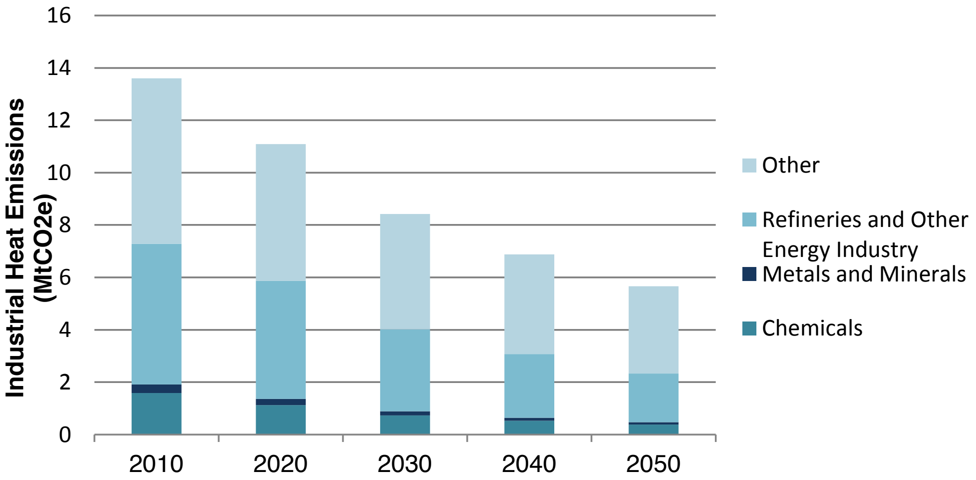

Figure 34. GHG emissions for the Industrial sector; High Government Intervention, Low Uptake Scenario.

The High GI, Low UT scenario indicates a total GHG reduction by 2050 of 18.2 $MtCO_2e/yr$ (68%), which is 22% greater than that in the Reference scenario. While Government has succeeded in ensuring consumers choose heat supply technologies on the basis of their marginal GHG abatement cost (MAC), a low level of Uptake acts as a drag on technology switching. Despite this, the share of fossil fuel-based technologies in the heating mix by 2050 is very much reduced compared to the Reference scenario for both domestic and non-domestic sectors.

After 2030, in both the Domestic and Non-domestic sectors there is a rising uptake of simple electric heating (e.g. resistive storage heaters), such that by 2050 it is contributing almost 30% of the Domestic heat demand, leading to a considerable additional load on the electricity grid (see Table 7). This trend is largely a result of the relatively low price and simplicity of the technology and the benefits of electrical grid decarbonisation rendering it "low carbon". It is also driven by consumers' resistance to new heating technologies such as heat pumps assumed in the scenario. Because simple electric heating is not the most efficient way of delivering heat via electricity, this scenario is somewhat of a challenge from an electrical grid infrastructure perspective; it requires significantly higher electrical generation and capacity reserves, which will be difficult to ensure alongside grid decarbonisation targets.

Non-domestic uptake of resistive (simple electric) heating also rises from 2030 onwards; a 33% increase in the annual demand met by resistive heating versus 2010. This scenario result for electric heating is not a preferable one, as heat delivery efficiencies of resistive heating are significantly lower than for heat pumps and would likely necessitate considerable additional electrical infrastructure. For this reason, high Uptake scenarios assume consumers have a better understanding of this issue and they therefore take up alternatives to resistive heating.

Heat pumps for both domestic and non-domestic buildings also contribute significantly to supply, along with district heating, whilst the role of biomass heating gradually increases to 2050, largely substituting oil-fired demand.

Refurbishment activity for the existing domestic and non-domestic sectors is relatively low, but high enough to prevent net increases in heat demand due to new-build stock additions, so no overall decrease is realised. The new-build stock for domestic and non-domestic buildings is pushed through regulations that ensure additions are highly energy efficient and any net emissions are offset by 2019 in both sectors.

In the industrial sector, CCS technology sees significant uptake by 2050 due to Government Intervention drivers, but low Uptake means heat is still delivered by the same sources as in 2010. The still relatively high reduction achieved is a product of assumed underlying efficiency trends and decrease in demand.

8.6 Scenario 4: High GI, High UT

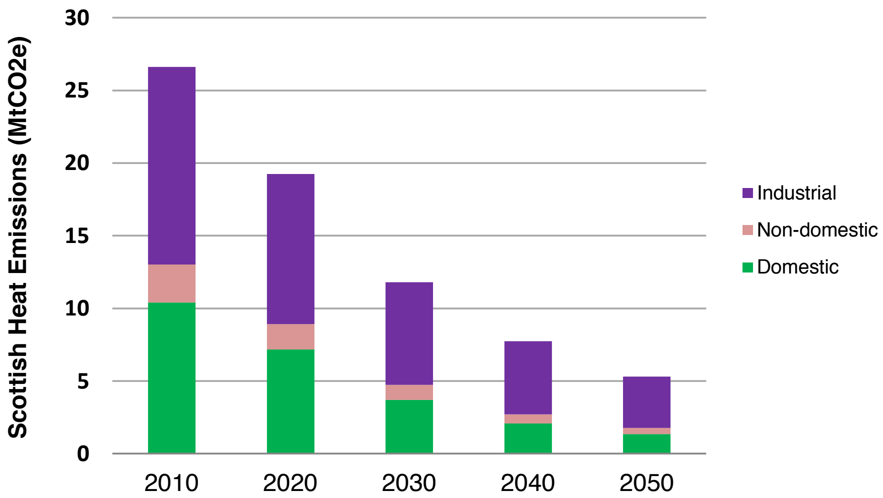

Figure 35. Total Scottish heat emissions; High Government Intervention, High Uptake Scenario

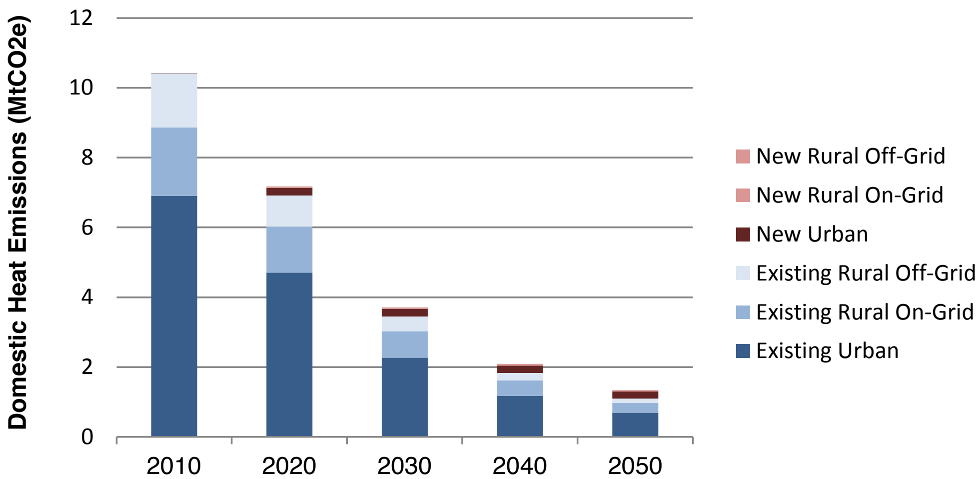

Figure 36. GHG emissions from heating for the domestic sector; High Government Intervention, High Uptake Scenario

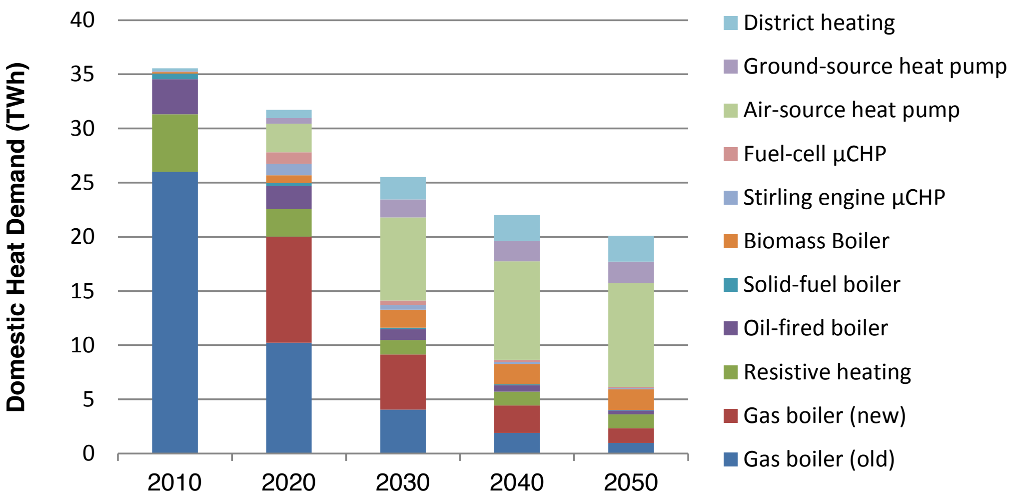

Figure 37: Domestic heat demand by supply type; High Government Intervention, High Uptake Scenario

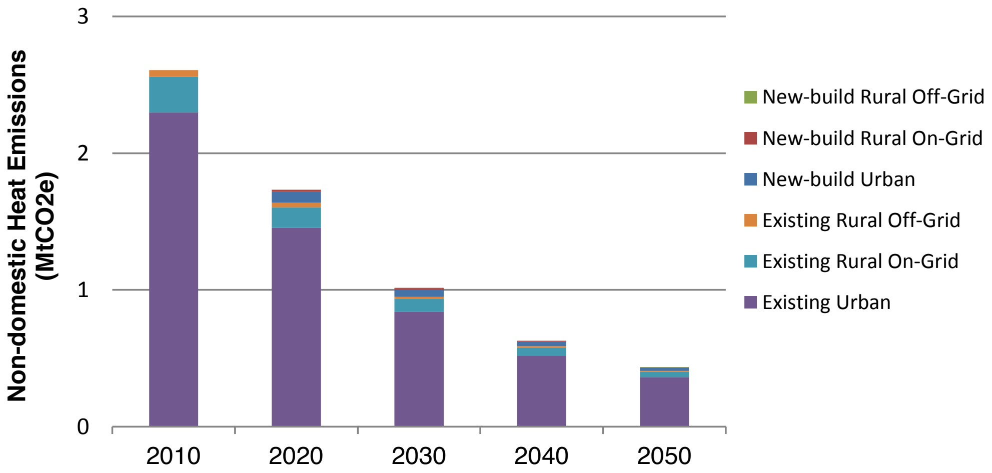

Figure 38: GHG emissions from heating for the Non-domestic sector; High Government Intervention, High Uptake Scenario

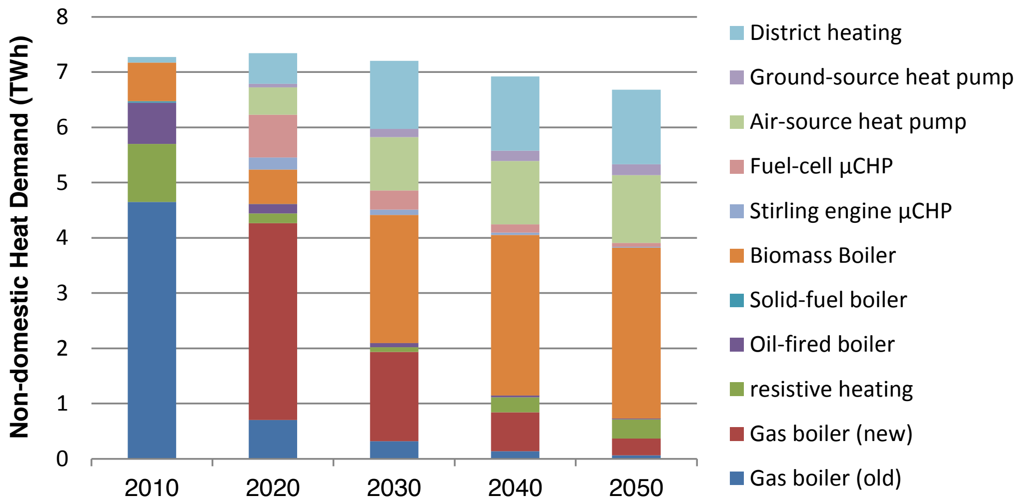

Figure 39. Non-domestic heat demand by supply type; High Government Intervention, High Uptake Scenario

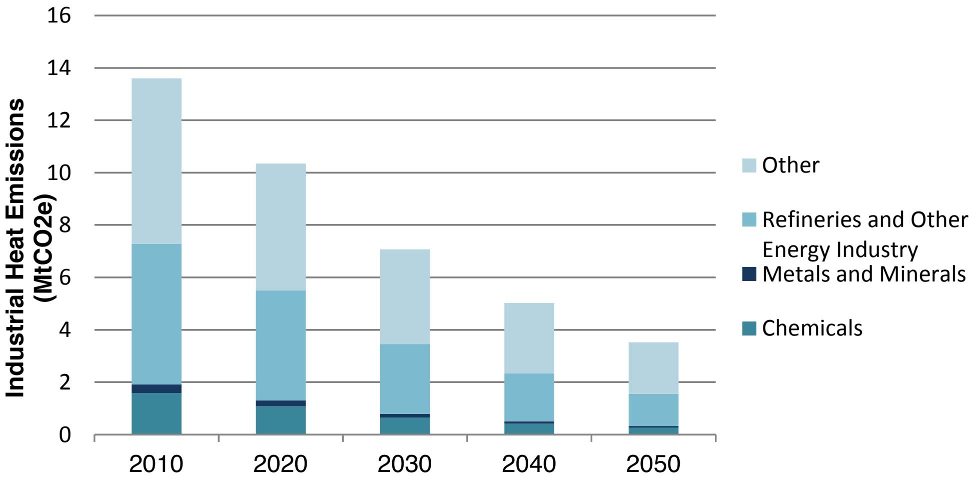

Figure 40. GHG emissions from heating for the Industrial sector; High Government Intervention, High Uptake Scenario

The High GI, High UT scenario represents the greatest level of heat decarbonisation. Emissions by 2050 are lower than the 2010 baseline by 21.6 $MtCO_2e$/yr, or 81%, and represent an additional 45% reduction by 2050 compared to the Reference scenario. This scenario also presents the only trajectory to exceed an 80% emissions reduction when compared to the 1990 emissions baseline estimate.

High Government Intervention in this scenario focusses primarily on rapidly ramping up regulations for new buildings, with high standards being required by 2022 and ambitious offsetting mechanisms already in place before 2020. Government also leads by example, with an increased fabric retrofit rate in public sector existing stock assisting in the progress of demand reduction.

Overall demand for heat in the non-domestic sector is reduced to 2050 by improved energy efficiency (through refurbishment) in the existing stock more than offsetting efficient new-build additions (which are kept low through regulation); the sector as a whole is able to achieve a GHG emissions reduction of some 85% over the 40-year period.

Emissions in the domestic sector are reduced by 89%. This is achieved at the demand side by a reduction in total heat demand of over 30%, a result of almost all potential refurbishment being achieved by 2050 and energy-efficient new homes. On the supply side there is a near complete transition away from on-site combustion of fossil fuels.

Heat supply technology choices are driven by marginal GHG abatement costs as a result of Government Intervention, whilst Uptake reinforces the preference for low-carbon solutions. Particularly in the domestic sector, modern electric heating technologies, i.e. heat pumps, have a very significant role, providing 57% of all heat. Whilst far more efficient than simple electric heating (such as storage heaters), heat pumps in this scenario do still lead to increased electrical demands and capacity requirements compared to the Reference scenario; winter peak shocks could lead to nearly twice the required available electrical capacity, but electrical consumption is only 32% higher. Notably, the demands on the electrical infrastructure for this scenario are far reduced compared to the High GI, Low UT scenario.

Both the domestic and non-domestic sectors retain some resistive heating out to 2050, although in both cases total demand met is reduced significantly compared to 2010.

Non-domestic biomass again gains a substantial share of the market by 2050 under this scenario, supplying around 46% of all heat.

Elsewhere in the non-domestic sector trajectory, micro-CHP technologies, in particular fuel cells, gain a material share of the supply system in the 2020s and 2030s, largely due to favourable feed-in tariffs for electricity and a significant reduction in capital costs assumed. However, these are mostly forced out of the mix in the 2040s by electric heating technologies which benefit from a decarbonising electrical grid and thus lower marginal GHG abatement costs.

District heating plays a notable role in domestic and non-domestic sectors. In the non-domestic sector, in particular, district heating networks supply low-carbon heat to 21% of all demand. Biomass gains a very substantial share of the non-domestic market by 2050 under this scenario, supplying over 40% of all energy for space heating and hot water.

Industrial sector emissions are reduced by 74% by 2050 through the application of CCS (driven by high Government Intervention) and significant fuel switching away from liquid and solid fossil fuels to cleaner natural gas, low-carbon electricity and biomass.

8.7 District heating

This section provides a brief summary of the District Heating (DH) module results, with a focus on the domestic sector. Table 9 gives the total heat demand that is met by DH systems under the various scenarios. Figure 41 below indicates the number of homes connecting to DH schemes under the various scenarios. It can be observed that the Low GI scenarios and the Reference scenario conditions result in higher uptake of DH after 2030. The High GI scenarios see lower penetrations of DH due to on-site low carbon options offering greater carbon savings and lower MACs after this point as a result of grid decarbonisation; while DH supply systems are still low-carbon (see Figure 42), they must contend with distribution losses. Also, customer-side DH technology[36] is not assumed to drop in cost at the same rate as some of the other on-site supply technologies.

Table 9. Total demand met by DH under the different scenarios

Scenario	Units	2010	2020	2030	2040	2050
Low GI, Low UT	TWh	0.3	1.6	3.9	6.1	8.2
Low GI, High UT	TWh	0.3	1.6	3.9	6.0	8.0
High GI, Low UT	TWh	0.3	1.5	3.8	6.0	8.1
High GI, High UT	TWh	0.3	1.5	3.9	5.6	7.3
Reference	TWh	0.3	1.6	3.6	5.6	7.4

[36] Heat interface units, meters and distribution pipework

Figure 42 shows how the contribution of different DH supply technologies varies out to 2050 for the Low and High GI scenarios. The same profiles follow regardless of UT level; the choice between MAC and NAC is the main model driver for these splits.

Under the High GI scenario, gas CHP starts to phase out rapidly after 2020; by 2030 the electricity grid has decarbonised to the extent that gas CHP offers no further carbon savings and so is not a viable choice for consumers. In both High and Low GI scenarios there is a considerable role for large-scale heat pumps, secondary / waste heat recovery, and geothermal technologies by 2050, but in both cases biomass CHP and straight biomass boilers are indicated as supplying the majority of demand. Energy from waste installations and heat recovery from large-scale power stations are significant early contributors to the mix, but are ultimately constrained by available supply, i.e. power / EfW generating sites.

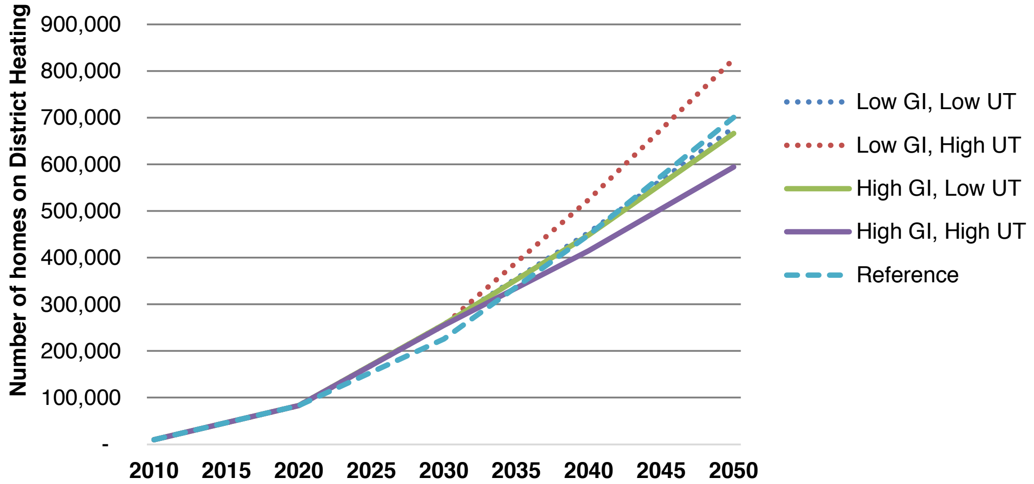

Figure 41. Homes connected to DH networks in Scotland, all scenarios

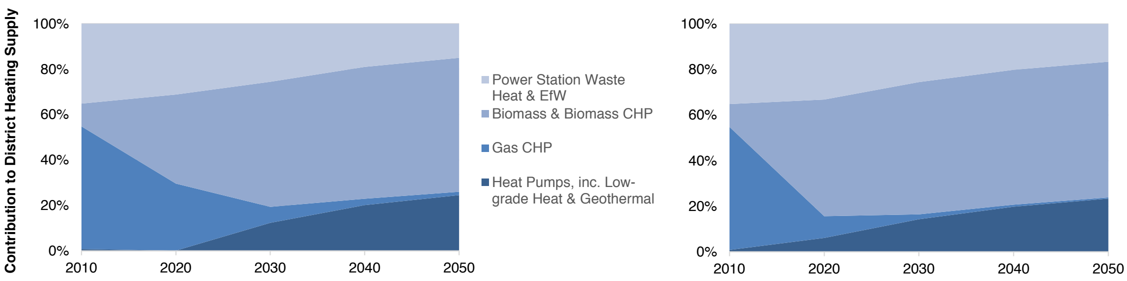

Figure 42. Heat supply split projections for DH networks under Low (left) and High (right) GI scenarios.

8.8 Household fuel consumption and costs

Through our scenario modelling it is possible to give an indication on the impact of the various scenario drivers on domestic fuel consumption and costs. The below figures present the changes in average values, calculated from the HPSM, for per-household heat and hot water (not fuel) demand, and average per-household fuel costs (not bills). It should be noted that all costs calculated in the HPSM are based on a single projection of future costs, and do not represent actual bills; the model does not consider subsidy for specific demographic groups or market dynamics in response to fuel price signals.

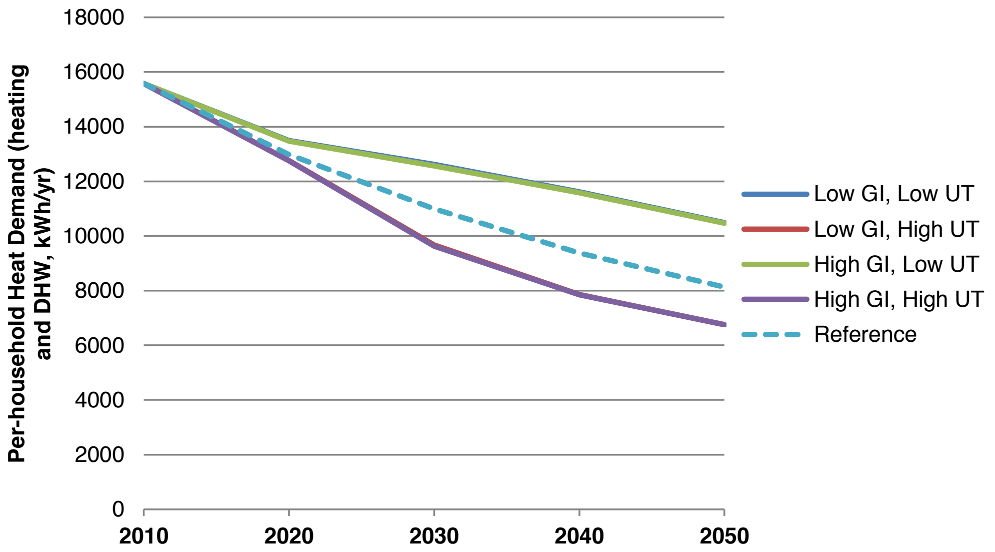

Figure 43. Per-household heat (not fuel) demand for space heating and hot water under the 5 scenarios. Note, both Low UT scenarios follow the same path as each other, as do both High UT scenarios.

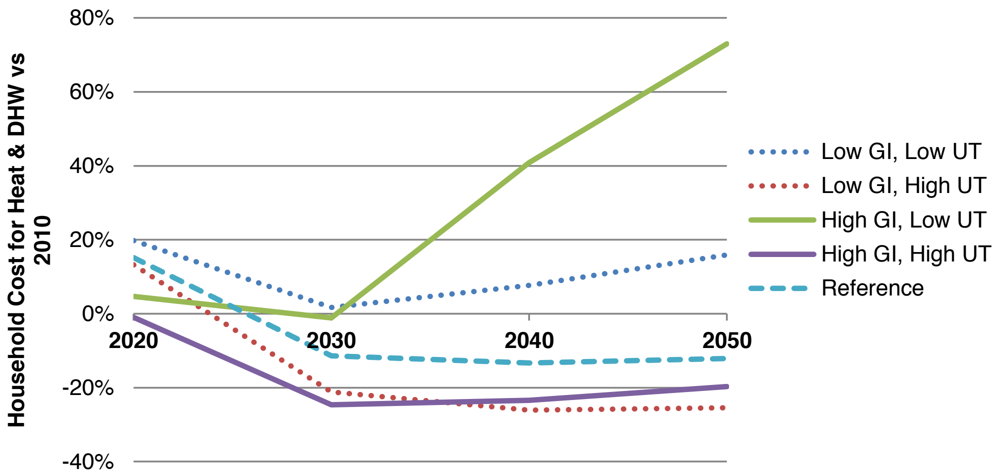

Figure 44. Change vs. 2010 in per-household costs for fuel to meet heat, hot water and cooking demands.

The above figures identify some notable items. Regarding heat demand, it can be seen that, directly as a result of the way the scenarios are defined, household demand for heat is highly dependent on the level of Uptake assumed. While Government Intervention does impact new-build standards and hence heat demand, the significance of the new-build sector is outweighed by the impact of retrofit measures affecting heat losses, and consumption trends, all of which are associated with Uptake in the HPSM.

As expected, high levels of Uptake cause the greatest reductions in per-household heating demand (over 50% compared to 2010).

The choice of fuel systems is the strongest driver for fuel costs after heat demand, and is impacted by both Uptake and Government Intervention drivers. In three out of the five scenarios, per-household average fuel costs in 2050 are reduced compared to 2010, despite all fuel unit prices increasing significantly over that period. The High Government Intervention, Low Uptake scenario sees household heating costs increase by 73%. This is due to a combination of lower demand reduction by 2050, but also Uptake leading consumers to choose more inefficient simple (resistive) electric heating in response to Government Intervention. Given the significant cost increases associated with this, this aspect of the scenario is likely unrealistic. This highlights that caution should be used when examining disaggregated results of the model.

8.9 Biomass usage

Most of the scenarios presented require a significant scaling up of biomass supply for heating. This section presents a brief, simple analysis of the potential for domestic and foreign supplies of biomass to meet these demands. A simple, maximum potential for solid biomass (not including biofuels or wastes) is provided below based on analysis of Forestry Commission figures[37]. Based on an assumed green density of 700 kg/m^3, dry weight of 50% of green weight, and gross calorific value of 20 MJ/kg, 25-year forecasts of softwood availability have been converted to TWh of available supply for heating. Annual availability figures for 2030 are assumed to remain constant to 2050.

Table 10 below provides an estimate of the total demand for biomass in green tonnes by 2050 for each scenario. This is calculated from the total energy demand in TWh met by biomass sources, but is only indicative, as the HPSM does not distinguish between the various available biomass feedstock forms and types (woodchips, wood pellets, switchgrass, short/long rotation coppice etc.).

Table 10. Total estimated biomass demand by 2050 for the various scenarios

	Reference	Low GI, Low UT	Low GI, High UT	High GI, Low UT	High GI, High UT
Biomass demand by 2050 (thousand green tonnes)	3,500	2,700	5,700	3,500	6,400

Figure 45 below shows the scale of heat demand from biomass by 2050 under the various scenarios. It provides an indicative estimate of where the biomass would be sourced from, based on the assumption that 50% of Scottish biomass production is available for heat use, whilst 10% of other UK sources is also available. The difference between supply and demand is met by imports.

It is cautioned that the majority of existing Scottish timber production is already consumed by existing industries (some of which are inherent in the model), and the diversion of existing supply for heat use will depend very much on market signals and interactions. Analysis of the barriers to uptake of biomass energy in Scotland is beyond the scope of this study.

Regarding imports, information provided by Forth Energy indicates that existing Scottish ports would have the capacity to import the entire incremental demand

[37] http://www.forestry.gov.uk/forestry/infd-8rce2q

for biomass assumed under the various scenarios without significant modification to existing infrastructure.

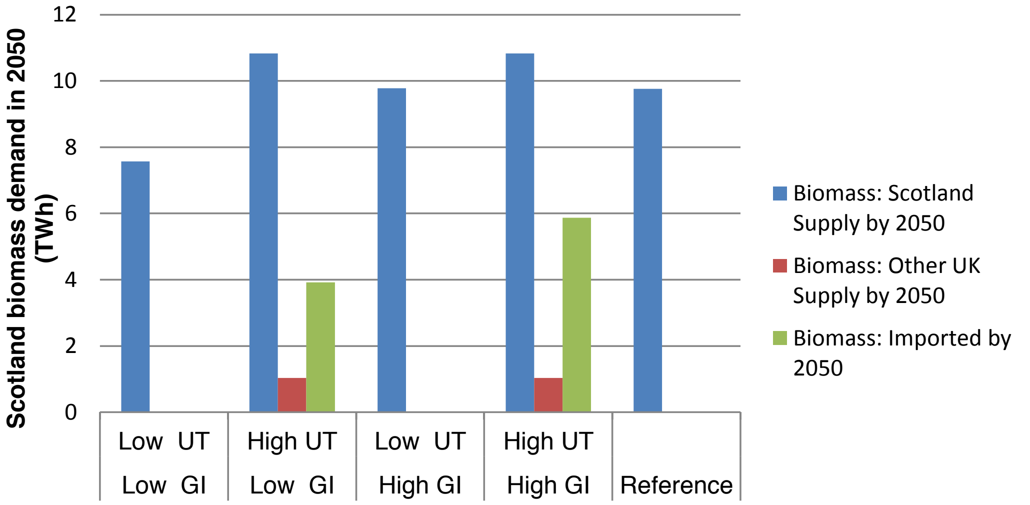

Figure 45. Biomass demand for Scottish heat in 2050 by supply source, indicative comparison for all scenarios

9 Report on Stakeholder Engagement

During the development of the model, we sought the input of stakeholders through two main methods:

- regular dialogue and reviews by a Steering Group made up of relevant staff from across the Scottish Government and Scottish Enterprise
- two days of workshops attended by external stakeholders from public, business and academic sectors

The Steering Group's input is embedded in the model and other outputs and is confirmed through final acceptance of the project deliverables. Therefore no additional description of this input is warranted.

The external stakeholder events took place in October 2013 and comprised three 2.5-hour discussion workshops. The format of each workshop was identical but the attendees were grouped into different themes:

- 2020 Groups
- Individual solutions
- District heating

Oral and written feedback from stakeholders on the data sources, assumptions, modelling approach and scenario definitions were provided at the meetings, with additional comments by email received over the subsequent two weeks.

The key comments or issues of note arising from the workshop are listed below:

- The inclusion/addition of secondary or waste heat sources;
- Clarity on the future use of the model and how it would be used to generate targets in relation to heat;
- Inclusion of the impact of unconventional gas, including syngas, hydrogen and biomethane in the model, and their injection into the existing gas grid;
- The limitations on biomass availability in Scotland and related constraints, such as port size and imports of wood pellets and other sources;
- The refurbishment rates and therefore heating system replacement rates for commercial and industrial sectors are far faster than those for the domestic sector;
- The inclusion of constraints around the Carbon Reduction Commitment (CRC);
- The consideration of technology innovations and taking account of them as far as possible;
- Regulation as a key incentive to drive forward new heating schemes; and
- The role of financial rewards and regulation in driving change of domestic heating systems.

We have provided in Appendix C a full record of notes taken, and the responses provided, during the workshops. This record should be referred to for further details of comments received.

Appendix A

Input and output variables schedules

A1 Explanatory note

The tables overleaf set out the input variables and output variables used for the Scottish Heat Pathway Scenarios Model (HPSM). Data sources are listed by reference to the full data sources list at Appendix B.

A1.1 Common Inputs

A1.1.1 Exogenous Driver Assumptions

Table 11. Existing domestic exogenous drivers

Existing Domestic Stock	2010	2020	2030	2040	2050
Number of Households Urban	1,782,380	1,764,636	1,747,069	1,729,677	1,712,458
Number of Households Rural On-Grid	376,100	372,356	368,649	364,979	361,346
Number of Households Rural Off-Grid	198,950	196,969	195,009	193,067	191,145
Population: Urban	3,935,040	3,895,866	3,857,082	3,818,685	3,780,669
Population: Rural On-grid	841,520	833,143	824,849	816,637	808,507
Population: Rural Off-grid	445,540	441,105	436,713	432,366	428,062

Table 12. New-build domestic exogenous drivers

New-build Domestic Stock	2010	2020	2030	2040	2050
Number of Households Urban		204,223	389,872	574,338	772,225
Number of Households Rural On-Grid		30,914	56,996	81,317	107,103
Number of Households Rural Off-Grid		20,615	37,599	52,809	68,868
Population: Urban		256,906	463,706	639,444	834,208
Population: Rural On-grid		37,129	66,986	88,431	114,657
Population: Rural Off-grid		21,697	36,260	45,222	56,551

Based on Scottish Government Population and Household Projections (2010 based)

http://www.gro-scotland.gov.uk/statistics/theme/population/projections/sub-national/2010-based/tables.html

http://www.gro-scotland.gov.uk/statistics/theme/households/projections/2010-based/tables.html

Table 13. Utility price assumptions

Utility Prices (p/kWh)		2010	2020	2030	2040	2050
Coal Residential		3.8	4.7	4.7	5.7	6.8
Coal Services		3.8	4.7	4.7	5.7	6.8
Biomass Pellets		5.0	5.4	5.7	6.9	8.4
Electricity (Retail Price)	Residential	13.5	19.1	19.0	22.9	27.6
	Services	8.4	12.7	13.5	16.3	19.7
	Industrial	7.1	11.4	12.1	14.6	17.6
Burning Oil	Residential	4.4	5.8	6.5	7.8	9.4
Gas Oil	Services	5.2	6.7	7.5	9.0	10.8
Gas Oil	Industrial	5.0	6.5	7.2	8.7	10.5
Gas (Retail Price)	Residential	3.8	5.5	5.4	6.5	7.8
	Services	2.5	3.7	3.9	4.7	5.6
	Industrial	1.9	3.1	3.2	3.9	4.7

Based on DECC UEPs: https://www.gov.uk/government/collections/energy-and-emissions-projections

Table 14. Seasonal external temperature projections

Average External Temperatures	2010	2020	2030	2040	2050
Winter	3.41	3.64	3.93	4.18	4.42
Spring	7.17	7.41	7.67	7.98	8.28
Summer	13.94	14.33	14.69	15.16	15.61
Autumn	9.19	9.50	9.74	10.11	10.54

Absolute future climate values calculated by combining baseline climatology (from Met Office gridded observational datasets described at: http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcip.html) with UKCP09 projections of future climate. 25km grid in vicinity of Huntly. http://ukclimateprojections.defra.gov.uk/23207

Table 15. Grid decarbonisation trajectory assumed

Grid Decarbonisation Trajectory	2010	2020	2030	2040	2050
$kgCO_2e/kWh$	0.479	0.210	0.096	0.035	0.013

Based on DECC UEPs: https://www.gov.uk/government/collections/energy-and-emissions-projections

A1.1.2 Technology Property Assumptions

In the following tables for domestic and non-domestic systems, "contributing sources" are those that were used to build up the HPSM's assumptions. For ease of reading, these are given as numbers, indicating the following references:

1) DCLG, 2011
2) DECCa, 2013
3) DECCe ,2009
4) DECCf, 2009
5) DECCg, 2013
6) Delta EE, 2012
7) Energy Saving Trust, 2013
8) Data from Scottish Government home renewables loan scheme, provided to Arup by Energy Saving Trust, 28 Oct 2013.
9) Mayor of London, 2013
10) Scottish Government d, 2013
11) Scottish Government e, 2013
12) Scottish Government f, 2011

Where a numbered source is referred to, (depending on the form of data in the source) the representative value from that study, the central case value from that study, or the mid-point between maximum and minimum of that study has been taken. Average values from all the sources used for a technology are calculated, as a means of removing the wide variation that is seen between some studies and produce a representative value for the model.

Table 16. Domestic heat supply technology properties assumed

Existing / New-build	Technology	Contributing Sources	2010 CAPEX (£000s per unit)	CAPEX reduction by 2050 (%)	Lifetime (years)	Maintenance Cost (£/unit/year)	Heat Efficiency (%)	Electrical Efficiency (CHP, %)
Existing Domestic	Gas boiler	2, 3, 7	2.8	-5%	15	180	93%	
	Resistive Heating	2, 3, 7	3.1	-5%	15	98	95%	
	Oil-fired boiler	2, 3, 7	3.7	-5%	15	310	89%	
	Solid-fuel boiler	2	7.3	-5%	15	520	87%	
	Biomass Boiler	2,3,4,5,6,7,8	11.3	-16%	15	180	88%	
	Stirling engine µCHP	2,6	9.6	-35%	15	180	63%	23%
	Fuel-cell µCHP	2,6	12.7	-35%	15	180	45%	45%
	Air-source heat pump	2,3,4,5,6,7,8	9.6	-23%	18	93.5	250%	
	Ground-source heat pump	2,3,4,5,6,7,8	12.8	-23%	23	79.75	288%	
	Solar Thermal	2,3,4,5,6,7,8	4.6	-29%	20	70	50%	
	District Heating	4	7.5	0%	20	25	90%	
New-build Domestic	Gas boiler	2, 3, 7	2.8	-5%	15	180	93%	
	Resistive Heating	2, 3, 7	3.1	-5%	15	98	95%	
	Oil-fired boiler	2, 3, 7	3.7	-5%	15	310	89%	
	Solid-fuel boiler	2	7.3	-5%	15	520	87%	
	Biomass Boiler	2,3,4,5,6,7,8	11.3	-16%	15	180	88%	
	Stirling engine µCHP	2,6	9.6	-35%	15	180	63%	23%
	Fuel-cell µCHP	2,6	12.7	-35%	15	180	45%	45%
	Air-source heat pump	2,3,4,5,6,7,8	9.6	-23%	18	93.5	295%	
	Ground-source heat pump	2,3,4,5,6,7,8	12.8	-23%	23	79.75	358%	
	Solar Thermal	2,3,4,5,6,7,8	4.6	-29%	20	70	50%	
	District Heating	4	7.5	0%	20	25	90%	

Table 17. Non-domestic heat supply technology properties assumed

Existing / New-build	Technology / Measure	Contributing Sources	2010 CAPEX (£/MWh)	CAPEX reduction by 2050 (%)	Lifetime (years)	Maintenance Cost (£/MWh)	Heat Efficiency (%)	Electrical Efficiency (CHP, %)
Existing Non-domestic	Gas boiler	2,3,7	35.6	-5%	15	2.81	94%	
	Resistive Heating	2,3,7	120.9	-5%	15	2.38	100%	
	Oil-fired boiler	2,3,7	65.2	-5%	15	2.04	89%	
	Solid-fuel boiler	2	154.6	-5%	15	3.70	87%	
	Biomass Boiler	1,2,3,4,5,7	137.9	-20%	15	5.45	84%	
	Stirling engine µCHP	2	183.0	-59%	15	6.15	63%	23%
	Fuel-cell µCHP	2	237.7	-61%	15	6.15	45%	45%
	Air-source heat pump	2,3,5,7	186.0	-23%	20	0.58	400%	
	Ground-source heat pump	1,2,3,4,5,7	299.2	-26%	20	1.18	345%	
	Solar Thermal	2,3,4,7	2682.6	-31%	20	876.71	50%	
	District Heating	2,4,7	68.6	0%	20	1.43	90%	
New-build Non-domestic	Gas boiler	2,3,7	35.6	-5%	15	2.81	94%	
	Resistive Heating	2,3,7	120.9	-5%	15	2.38	100%	
	Oil-fired boiler	2,3,7	65.2	-5%	15	2.04	89%	
	Solid-fuel boiler	2	154.6	-5%	15	3.70	87%	
	Biomass Boiler	1,2,3,4,5,7	137.9	-20%	15	5.45	84%	
	Stirling engine µCHP	2	183.0	-59%	15	6.15	63%	23%
	Fuel-cell µCHP	2	237.7	-61%	15	6.15	45%	45%
	Air-source heat pump	2,3,5,7	186.0	-23%	20	0.58	400%	
	Ground-source heat pump	1,2,3,4,5,7	299.2	-26%	20	1.18	345%	
	Solar Thermal	2,3,4,7	2682.6	-31%	20	876.71	50%	
	District Heating	2,4,7	68.6		20	1.4	90%	

Table 18. District heating (DH) supply technology properties assumed

Technology / Measure	Contributing Sources	Maximum Delivery Potential	Units	2010 CAPEX (£/MWh)	CAPEX reduction by 2050 (%)	Lifetime (years)	Maintenance Cost (£/MWh)	Heat Efficiency (%)	Electrical Efficiency (CHP, %)
Air-source heat pump	2,3,7	50%	% of demand met by DH	217	-23%	20	0.33	400%	
Ground-source heat pump	2,3,7	20%	% of demand met by DH	400	-26%	20	0.33	413%	
Water-source heat pump		10%	% of demand met by DH	400	-26%	20	0.33	413%	
Geothermal	2,3,10,11	3%		415	-26%	20	8.50	100%*	
Community scale gas CHP	1,2,3,4,7	90%	% of demand met by DH	187	-15%	20	13.03	42%	40%
Community scale biomass CHP	1,2	30%	% of demand met by DH	372	-15%	20	12.90	57%	25%
Biomass boiler-only	3,4	90%	% of demand met by DH	202	-10%	20	8.25	84%	
Power Station Waste Heat (inc EfW)	2,4,12	5%		46	0%	40	0.33	100%*	
Direct Low Grade / Secondary Heat Recovery	3,9	34%	% of total 2010 urban heat demand	309	-20%	20	0.33	406%	

**Assumed transmission and distribution losses of 10% are accounted for elsewhere in the model.*

Technology Potentials

The below tables outline the assumptions used to determine maximum technical potential for the various technologies. Note that technical potential is in many cases somewhat higher than "practical" potential might be considered to be; technical potential merely sets an upper bound for the model. In most cases these potentials are never reached due to other limiting factors in the mode. Domestic potentials were derived from Arup analysis of the Scottish Housing Condition Survey, and in some instances high-level analysis of Home Analytics data carried out by the Energy Saving Trust for the Scottish Government.

Table 19. Existing domestic buildings, maximum heat supply technology potentials assumed

		Technology Potential (Number of homes)			
Sector	**Technology**	**Urban**	**Rural On-Grid**	**Rural Off-Grid**	**Rationale**
Existing Domestic	Gas boiler	1,541,212	325,211	-	*All urban buildings are assumed to be suitable for gas-fired heating. Likewise Rural on-grid, but none in rural off-grid.*
	Resistive Heating	1,541,212	325,211	172,031	*Any building with an electrical connection is suitable. This potential doesn't account for the possible impracticality of reinforcing grids in outer-rural areas.*
	Oil-fired boiler	382,221	13,984	8,602	*Only detached houses and flats assumed to be suitable.*
	Solid-fuel boiler	198,816	11,708	8,257	*Detached homes only; air quality issues.*
	Biomass Boiler	198,816	11,708	8,257	*Detached homes and flats only; need space for storage of fuel. Flats are assumed to have suitable space for plant within existing plant room.*
	Stirling engine µCHP	1,541,212	325,211	-	*Any home with a gas-connection or in a gas-connectable area.*
	Fuel-cell µCHP	1,541,212	325,211	-	*Any home with a gas-connection or in a gas-connectable area.*
	Air-source heat pump	1,541,212	325,211	172,031	*All buildings*
	Ground-source heat pump	568,707	20,163	12,386	*Detached and semi-detached only; garden space required.*
	Solar Thermal	479,096	153,485	40,761	*NB this does not imply all heat of homes indicated can be met by solar thermal; merely those homes can be served in some way by panels. Southern orientation roofs, not listed buildings, not flats, homes with hot water tanks. High-level analysis of Home Analytics provided by EST.*
	District Heating	528,636	-	-	*Not tenements. Not detached or semi-detached homes; imply too low a heat density for DH scheme economics. Flats included and terraced houses also. Rural areas assumed too low in "heat density".*

Table 20. New-build domestic buildings, maximum heat supply technology potentials assumed

Sector	Technology	Technology Potential (% of new-build stock) Urban	Rural On-Grid	Rural Off-Grid	Rationale
New-build Domestic	Gas boiler	100%	100%	0%	*As for existing.*
	Resistive Heating	100%	100%	100%	*As for existing.*
	Oil-fired boiler	67%	67%	45%	*As for existing.*
	Solid-fuel boiler	30%	30%	45%	*As for existing.*
	Biomass Boiler	100%	100%	100%	*Everything (no terraced housing assumed to be built).*
	Stirling engine µCHP	100%	100%	0%	*As for existing.*
	Fuel-cell µCHP	100%	100%	0%	*As for existing.*
	Air-source heat pump	100%	100%	100%	*As for existing.*
	Ground-source heat pump	50%	50%	50%	*Greater potential than existing as can lay piles or slinkies etc. during construction.*
	Solar Thermal	100%	100%	100%	*As for existing.*
	District Heating	37%	0%	0%	*Only flats (no terraced housing assumed to be built).*

Table 21. Existing non-domestic buildings, heat supply technology maximum potentials assumed

		Technology Potential (% of non-domestic existing stock)			
Sector	**Technology**	**Urban**	**Rural On-Grid**	**Rural Off-Grid**	**Rationale**
Existing Non-domestic	Gas boiler	100%	100%	0%	
	Resistive Heating	100%	100%	100%	
	Oil-fired boiler	75%	75%	75%	
	Solid-fuel boiler	75%	75%	75%	
	Biomass Boiler	75%	100%	100%	*Rural off-grid properties assumed to have greater space availability than Urban.*
	Stirling engine µCHP	100%	100%	0%	
	Fuel-cell µCHP	100%	100%	0%	
	Air-source heat pump	20%	20%	20%	
	Ground-source heat pump	5%	10%	10%	
	District Heating	75%	10%	10%	

Table 22. New-build non-domestic buildings, heat supply technology maximum potentials assumed

Sector	Technology	Technology Potential (% of non-domestic new-build stock) Urban	Rural On-Grid	Rural Off-Grid	Rationale
New-build Non-domestic	Gas boiler	100%	100%	0%	
	Resistive Heating	100%	100%	100%	
	Oil-fired boiler	100%	100%	100%	
	Solid-fuel boiler	75%	75%	75%	
	Biomass Boiler	100%	100%	100%	*Rural off-grid properties assumed to have greater space availability than Urban.*
	Stirling engine µCHP	100%	100%	0%	*Straightforward to incorporate in new building designs.*
	Fuel-cell µCHP	100%	100%	0%	*Straightforward to incorporate in new building designs.*
	Air-source heat pump	100%	100%	100%	*Straightforward to incorporate in new building designs.*
	Ground-source heat pump	25%	35%	35%	*Greater potential than existing as can lay piles or slinkies etc. during construction.*
	District Heating	100%	100%	100%	

Fabric Retrofit Technical Properties and Potentials

As for the heat supply systems indicated in the tables above, the following table indicates the maximum potential for retrofit in the domestic sector. These have been derived from analysis of the SHCS.

Table 23. Domestic fabric retrofit assumed thermal performance values and maximum uptake potentials assumed

		Technology Potential (% of entire building stock)			
Technology	**U-Value assumed following retrofit (W/m^2K)**	**Urban**	**Rural On-Grid**	**Rural Off-Grid**	**CAPEX (£000s)**
Solid Walls	0.35	18%	2.2%	3.6%	3.0
Cavity Walls	0.35	65%	6.0%	4.6%	0.4
Floors	0.15	76%	16%	8%	0.7
Windows	0.8	76%	16%	8%	2.6
Lofts	0.05	49%	7%	8%	0.4
Draft-proofing	5 (Q50 permeability)	76%	16%	8%	0.7
Thermal Bridging	0.1	76%	16%	8%	1.5

A1.1.3 Common Data Inputs & Assumptions

Table 24. Household space heating and hot water delivery, by geography, in 2010

<table>
<tr><th>Geography</th><th>Heating fuel type</th><th>% of total housing stock</th><th>% of Geography Category</th></tr>
<tr><td rowspan="6">Urban</td><td>Gas</td><td>70.6%</td><td>85.3%</td></tr>
<tr><td>LPG & bottled gas</td><td>0.0%</td><td></td></tr>
<tr><td>Oil</td><td>0.4%</td><td>0.5%</td></tr>
<tr><td>Solid Fuel</td><td>0.3%</td><td>0.4%</td></tr>
<tr><td>Electric</td><td>10.6%</td><td>12.8%</td></tr>
<tr><td>Community Heat</td><td>0.9%</td><td>1.1%</td></tr>
<tr><td></td><td>Subtotal</td><td>82.8%</td><td></td></tr>
<tr><td rowspan="6">Rural On-Grid</td><td>Gas</td><td>5.9%</td><td rowspan="2">70.6%</td></tr>
<tr><td>LPG & bottled gas</td><td>0.1%</td></tr>
<tr><td>Oil</td><td>1.2%</td><td>14.1%</td></tr>
<tr><td>Solid Fuel</td><td>0.2%</td><td>2.4%</td></tr>
<tr><td>Electric</td><td>1.1%</td><td>12.9%</td></tr>
<tr><td>Community Heat</td><td>0.0%</td><td>0.0%</td></tr>
<tr><td></td><td>Subtotal</td><td>8.5%</td><td></td></tr>
<tr><td rowspan="5">Rural Off-Grid</td><td>LPG & bottled gas</td><td>0.7%</td><td>6.5%</td></tr>
<tr><td>Oil</td><td>4.4%</td><td>51.8%</td></tr>
<tr><td>Solid Fuel</td><td>0.8%</td><td>9.4%</td></tr>
<tr><td>Electric</td><td>2.6%</td><td>30.6%</td></tr>
<tr><td>Community Heat</td><td>0.0%</td><td>0.0%</td></tr>
<tr><td></td><td>Subtotal</td><td>8.5%</td><td></td></tr>
</table>

Table 25. Household cooking energy source, 2010

Geography	Cooking Fuel Type	% of Geography Category
Urban	Gas	85.3%
	Electric	14.7%
Rural On-Grid	Gas	70.6%
	Electric	29.4%
Rural Off-Grid	LPG / Bottled Gas	6.5%
	Electric	91.8%

Table 26. New-build housing stock distribution, adjusted from DEMScot assumptions

Geography	Type	% of new house building by geography
Urban	Mid-Terraced	
	Semi-Detached	33%
	Detached	30%
	Tenement	
	Flat	37%
Rural On-grid	Mid-Terraced	
	Semi-Detached	33%
	Detached	30%
	Tenement	
	Flat	37%
Rural Off-Grid	Mid-Terraced	
	Semi-Detached	55%
	Detached	45%
	Tenement	
	Flat	

Table 27. New-build fabric standards, as per Zero Carbon Hub, 2009.

Package	Window U-value (W/m^2K)	Floors U-value (W/m^2K)	Walls U-value (W/m^2K)	Roof U-value (W/m^2K)	Air permeability ($m^3/m^2.hr$)	Thermal Bridging (W/m^2K)	Cost vs. baseline (£k)
Part L 2006 (NV, ZCH Baseline)	1.8	0.2	0.28	0.16	7	0.08	
ZCH Spec A (NV)	1.5	0.2	0.25	0.15	5	0.06	1.17
ZCH Spec C (MVHR)	1.2	0.15	0.15	0.11	3	0.04	7.68
ZCH Spec D (Passiv Haus)	0.9	0.13	0.13	0.10	1	0.04	11.28

Table 28. New-build dimensions assumed for the domestic sector.

Building Type	Semi-Detached	Detached	Tenement	Flat
Total Floor Area (m^2)	88	146	64	53
Assumed Footprint (m^2)	51	97	28	53
Roof Area (m^2)	51	96	20	21
Window Net Area (m^2)	14	21	10	7
Door Area (m^2)	3.8	3.8	1.9	1.9
Wall Area (m^2)	72	101	37	40
Net Fabric Area (m^2)	192	319	97	124

Table 29. New-build dimensions assumed for non-domestic building archetypes, as per DCLG, 2011.

Archetype	Stories	Floor Height (m)	Width (m)	Length (m)	Floor / Roof Area (m)	Wall Area (m^2)	Glazing (% of Wall Area)	Volume (m^3)
Shallow Plan	6	3.7	15	60	900	3330	0.6	3330
Deep Plan	6	3.7	30	30	900	2664	0.6	3330
Shed	2	4	25	40	1000	1040	0.6*	4000

**% of front façade*

Table 30. New-build fabric performance levels; assumed thermal properties and costs, based on DCLG, 2011.

	Roofs (W/m^2K)	Walls (W/m^2K)	Floors (W/m^2K)	Glazing U, g, TL	Permeability (m^3/hr.m2.yr)	Cost vs. baseline* (£/m2)
Baseline	0.25	0.35	0.25	2, 0.7, 0.8	3	
Level A	0.2	0.25	0.2	1.6, 0.41, 0.67	3	9-24
Level B	0.15	0.2	0.15	1.3, 0.41, 0.67	3	23-68
Level C	0.1	0.15	0.1	0.8, 0.6, 0.74	3	43-111

**varies depending on archetype*

Table 31. Great Britain and Scotland maximum biomass potential, based on high-level analysis of Forestry Commission projections, as discussed in Section 8.9.

Max available supply (TWh per Year)	2020	2030	2040	2050
Great Britain	29.7	34.7	32.0	32.0
Scotland	18.4	24.2	21.7	21.7
Rest of Great Britain	11.3	10.5	10.4	10.4

A1.2 Scenario Inputs

This section outlines the only inputs to the scenarios model. These values combine with the exogenous drivers and sector performance models to project heat and energy demand, and emissions to 2050 for the four main scenarios and the Reference scenario.

A1.2.1 Government Intervention

The below tables present the assumptions used for scenario drivers under the Government Intervention category. For capital and operating support assumptions, the Low Government Intervention scenario assumes the support is removed after the 2010 decade. The High Government Intervention scenario, meanwhile, assumes a continuation of support through to 2050, with the exception of boiler scrappage incentives.

Table 32. Capital and operating support assumptions

Technology	Sector	Heat Revenues (£/kWh_{th})	Electricity Export Revenues (£/kWhe)	Capital subsidy (£/unit)
Gas boiler (new)	Domestic			400
Biomass boiler	Domestic	0.122		2,000
Stirling engine µCHP	Domestic		0.125	
Fuel-cell µCHP	Domestic		0.125	
Air-source heat pump	Domestic	0.073		1,300
Ground-source heat pump	Domestic	0.188		2,300
Solar Thermal	Domestic	0.192		600
Biomass boiler	Commercial	0.065		
Air-source heat pump	Commercial	0.02		
Ground-source heat pump	Commercial	0.055		
Solar Thermal	Commercial	0.17		

Table 33. Government Intervention scenario driver values assumed

		Reference	LOW	HIGH
Domestic				
Year given fabric standard comes into effect	Equivalent BR 2013 Standard	2015	2015	2015
	Equivalent BR 2016 Standard	2018	2020	2018
	Passiv Haus Equivalent	2030	2030	2022
	Enacting of Zero Carbon Homes Standard (AS)	2030	2030	2019
Non-Domestic				
Year given fabric standard comes into effect	Level A Thermal Standard	2015	2015	2015
	Level B Thermal Standard	2019	2022	2018
	Level C Thermal Standard	2025	2035	2022
	Enacting of Zero Carbon Non-domestic Standard	2030	2030	2019
Industrial				
CCS in sector by 2050 (% of emissions captured)	Chemicals	0%	0%	40%
	Metals and Minerals	0%	0%	25%
	Refineries and Other Energy Industry	0%	0%	50%
	Other	0%	0%	5%
Leading by example				
Change in fabric retrofit rate (% vs. BAU)	Education	0%	0%	40%
	Government	0%	0%	40%
	Health	0%	0%	40%

A1.2.2 Uptake

Table 34. Uptake scenario driver values assumed

		Reference	LOW	HIGH
Demand Factors				
Behaviour change by 2050	Change in average domestic internal temperature	-2%	5%	-5%
	Change in non-domestic heat demand	-2%	0%	-5%
	Change in DHW consumption	0%	5%	-10%
Non-Domestic				
Increase in fabric retrofit rate (%)	Commercial Offices	0%	0%	20%
	Communication and Transport	0%	0%	20%
	Hotel and Catering	0%	0%	20%
	Other	0%	0%	20%
	Retail	0%	0%	20%
	Sport and Leisure	0%	0%	20%
	Warehouses	0%	0%	20%
Industrial				
Fuel Split by 2050				
Chemicals	Electricity	22%	18%	25%
	Natural Gas	70%	76%	49%
	Oil	4%	4%	4%
	Solid Fuel	2%	2%	2%
	Biomass	2%	0%	20%
Metals and Minerals	Electricity	36%	23%	50%
	Natural Gas	48%	47%	40%
	Oil	1%	2%	0%
	Solid Fuel	15%	29%	5%
	Biomass	0%	0%	5%
Refineries & Other Energy Industry	Electricity	19%	15%	20%
	Natural Gas	41%	39%	55%
	Oil	30%	40%	2%
	Solid Fuel	5%	5%	5%
	Biomass	5%	0%	18%
Other	Electricity	18%	8%	20%
	Natural Gas	30%	20%	44%
	Oil	41%	69%	15%
	Solid Fuel	1%	1%	1%
	Biomass	10%	3%	20%

Table 35. Uptake limiting rates for domestic heat supply and demand measures.

Domestic		Reference	LOW	HIGH
Existing	Gas boiler	74%	90%	45%
	Resistive heating	21%	30%	5%
	Oil-fired boiler	23%	30%	10%
	Solid-fuel boiler	27%	30%	20%
	Biomass Boiler	61%	45%	90%
	Stirling engine µCHP	16%	15%	18%
	Fuel-cell µCHP	16%	15%	18%
	Air-source heat pump	32%	25%	45%
	Ground-source heat pump	29%	25%	35%
	Solar Thermal	61%	45%	90%
	District Heating	39%	33%	50%
	Demand Reduction (Fabric)	35%	10%	80%
***New**-build*	Gas boiler (new)	67%	90%	25%
	Resistive heating	27%	30%	20%
	Oil-fired boiler	27%	30%	23%
	Solid-fuel boiler	21%	30%	5%
	Biomass Boiler	61%	45%	90%
	Stirling engine µCHP	22%	20%	27%
	Fuel-cell µCHP	22%	20%	27%
	Air-source heat pump	44%	30%	70%
	Ground-source heat pump	37%	30%	50%
	Solar Thermal	61%	45%	90%
	District Heating	74%	65%	90%

Table 36. Uptake limiting rates for non-domestic heat supply and demand measures.

Non-domestic		Reference	LOW	HIGH
Existing	Gas boiler	58%	65%	45%
	Resistive heating	12%	15%	5%
	Oil-fired boiler	56%	80%	10%
	Solid-fuel boiler	15%	23%	1%
	Biomass Boiler	22%	10%	45%
	Stirling engine µCHP	21%	18%	27%
	Fuel-cell µCHP	21%	18%	27%
	Air-source heat pump	44%	40%	50%
	Ground-source heat pump	24%	20%	30%
	Solar Thermal	29%	20%	45%
	District Heating	19%	15%	25%
	Demand Reduction (Fabric)	41%	15%	90%
New-build	Gas boiler	51%	65%	25%
	Resistive heating	15%	20%	5%
	Oil-fired boiler	54%	80%	5%
	Solid-fuel boiler	32%	23%	50%
	Biomass Boiler	23%	25%	20%
	Stirling engine µCHP	21%	18%	27%
	Fuel-cell µCHP	21%	18%	27%
	Air-source heat pump	60%	54%	70%
	Ground-source heat pump	41%	36%	50%
	Solar Thermal	34%	30%	40%
	District Heating	30%	25%	40%

A1.3 Scenario Outputs

The following time series are the core, practical outputs from the HPSM scenario runs as described in this report. The model provides some further detail.

Time series for Capex and Opex are presented for each decade. It should be noted that Opex figures refer to the amount being spent on fuel, maintenance and the like in the decade in question. Capex figures, meanwhile, refer to the average annual spend on equipment, retrofit and new-build fabric measures in the preceding decade. I.e. Capex figures presented are the total expenditure for the preceding decade divided by ten.

Regarding delivered heat supply systems data, in the existing buildings sectors these refer to the heating systems installed in order to replace life-expired plant. In the new-build sector, the values refer to the systems installed in new buildings, but also (from 2020 onwards) systems that are installed as a result of replacement.

A1.3.1 Reference Scenario

Table 37. Heat Demands, Reference Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic *Space heating & DHW*	Urban	Existing	TWh	*25.69*	*22.75*	*20.20*	*17.99*	*16.23*
		New-build	TWh	*0.00*	*1.30*	*2.20*	*2.85*	*3.49*
		Urban Total	TWh	***25.69***	***24.05***	***22.40***	***20.84***	***19.72***
	Rural On-Grid	Existing	TWh	*6.81*	*5.95*	*5.21*	*4.58*	*4.09*
		New-build	TWh	*0.00*	*0.20*	*0.32*	*0.41*	*0.49*
		Rural On-Grid Total	TWh	***6.81***	***6.15***	***5.53***	***4.99***	***4.58***
	Rural Off-grid	Existing	TWh	*4.23*	*3.64*	*3.14*	*2.73*	*2.41*
		New-build	TWh	*0.00*	*0.16*	*0.26*	*0.32*	*0.37*
		Rural Off-Grid Total	TWh	***4.23***	***3.80***	***3.40***	***3.04***	***2.78***
Domestic Total			TWh	**36.73**	**34.00**	**31.33**	**28.87**	**27.08**
Non-domestic *Space heating & DHW*	Urban	Existing	TWh	*6.48*	*6.15*	*5.83*	*5.52*	*5.21*
		New-build	TWh	*0.00*	*0.51*	*0.83*	*1.02*	*1.24*
		Urban Total	TWh	***6.48***	***6.66***	***6.66***	***6.53***	***6.45***
	Rural On-Grid	Existing	TWh	*1.17*	*1.10*	*1.04*	*0.98*	*0.92*
		New-build	TWh	*0.00*	*0.06*	*0.09*	*0.12*	*0.14*
		Rural On-Grid Total	TWh	***1.17***	***1.16***	***1.13***	***1.10***	***1.06***
	Rural Off-grid	Existing	TWh	*0.11*	*0.11*	*0.10*	*0.10*	*0.09*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.03*
		Rural Off-Grid Total	TWh	***0.11***	***0.12***	***0.12***	***0.12***	***0.12***
Non-domestic Total			TWh	**7.75**	**7.94**	**7.91**	**7.75**	**7.64**
Industrial Total			TWh	**48.0**	**44.3**	**40.9**	**37.9**	**35.2**
	Catering & Cooking Demand		TWh	2.36	2.72	3.08	3.47	3.95
	Cooling Demand		TWh	1.27	1.42	1.61	1.91	2.29
	Total Heating and Cooling Demand for Scotland		TWh	**96.13**	**90.35**	**84.86**	**79.92**	**76.14**

Table 38. Total Energy Demand, Reference Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic	Urban	Existing	TWh	*29.09*	*24.40*	*20.54*	*18.08*	*16.34*
		New-build	TWh	*0.00*	*1.27*	*1.92*	*2.41*	*2.90*
		Urban Total	TWh	***29.09***	***25.67***	***22.47***	***20.49***	***19.24***
	Rural On-Grid	Existing	TWh	*7.65*	*6.33*	*5.02*	*4.26*	*3.76*
		New-build	TWh	*0.00*	*0.20*	*0.25*	*0.34*	*0.43*
		Rural On-Grid Total	TWh	***7.65***	***6.54***	***5.27***	***4.61***	***4.19***
	Rural Off-grid	Existing	TWh	*4.54*	*3.55*	*2.72*	*2.17*	*1.80*
		New-build	TWh	*0.00*	*0.16*	*0.20*	*0.27*	*0.33*
		Rural Off-Grid Total	TWh	***4.54***	***3.71***	***2.92***	***2.44***	***2.13***
Domestic Total			TWh	**41.27**	**35.92**	**30.67**	**27.53**	**25.55**
Non-domestic	Urban	Existing	TWh	*9.47*	*7.88*	*7.29*	*6.84*	*6.42*
		New-build	TWh	*0.00*	*0.59*	*1.04*	*1.42*	*1.90*
		Urban Total	TWh	***9.47***	***8.47***	***8.33***	***8.26***	***8.32***
	Rural On-Grid	Existing	TWh	*1.03*	*0.87*	*0.80*	*0.75*	*0.70*
		New-build	TWh	*0.00*	*0.08*	*0.12*	*0.17*	*0.23*
		Rural On-Grid Total	TWh	***1.03***	***0.95***	***0.92***	***0.92***	***0.93***
	Rural Off-grid	Existing	TWh	*0.15*	*0.14*	*0.13*	*0.12*	*0.11*
		New-build	TWh	*0.00*	*0.01*	*0.03*	*0.04*	*0.05*
		Rural Off-Grid Total	TWh	***0.15***	***0.15***	***0.16***	***0.16***	***0.16***
Non-domestic Total			TWh	**10.65**	**9.57**	**9.41**	**9.33**	**9.41**
Industrial		Chemicals	TWh	*6.0*	*5.3*	*4.6*	*4.0*	*3.5*
		Metals and Minerals	TWh	*1.0*	*0.9*	*0.8*	*0.7*	*0.6*
		Refineries and Other Energy Industry	TWh	*18.5*	*18.0*	*17.6*	*17.2*	*16.7*
		Other	TWh	*22.5*	*20.1*	*17.9*	*16.0*	*14.3*
Industry Total			TWh	**48.01**	**44.28**	**40.92**	**37.91**	**35.19**
Total Energy Demand for Heating and Cooling in Scotland			TWh	**99.93**	**89.76**	**81.00**	**74.77**	**70.15**

Table 39. GHG Emissions Summary, Reference Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	$MtCO_2e$	*6.91*	*4.90*	*3.85*	*3.25*	*2.89*
		New-build	$MtCO_2e$	*0.00*	*0.25*	*0.32*	*0.32*	*0.31*
		Urban Total	$MtCO_2e$	***6.91***	***5.15***	***4.18***	***3.56***	***3.20***
	Rural On-Grid	Existing	$MtCO_2e$	*1.96*	*1.37*	*1.00*	*0.80*	*0.68*
		New-build	$MtCO_2e$	*0.00*	*0.03*	*0.02*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***1.96***	***1.40***	***1.02***	***0.81***	***0.69***
	Rural Off-grid	Existing	$MtCO_2e$	*1.55*	*0.84*	*0.41*	*0.21*	*0.12*
		New-build	$MtCO_2e$	*0.00*	*0.02*	*0.01*	*0.01*	*0.01*
		Rural Off-Grid Total	$MtCO_2e$	***1.55***	***0.86***	***0.43***	***0.22***	***0.13***
Domestic Total			$MtCO_2e$	**10.41**	**7.41**	**5.62**	**4.59**	**4.02**
Non-domestic	Urban	Existing	$MtCO_2e$	*2.30*	*1.57*	*1.13*	*0.97*	*0.89*
		New-build	$MtCO_2e$	*0.00*	*0.05*	*0.09*	*0.09*	*0.08*
		Urban Total	$MtCO_2e$	***2.30***	***1.62***	***1.23***	***1.06***	***0.98***
	Rural On-Grid	Existing	$MtCO_2e$	*0.26*	*0.18*	*0.14*	*0.12*	*0.11*
		New-build	$MtCO_2e$	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***0.26***	***0.19***	***0.15***	***0.13***	***0.12***
	Rural Off-grid	Existing	$MtCO_2e$	*0.05*	*0.04*	*0.03*	*0.02*	*0.02*
		New-build	$MtCO_2e$	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Rural Off-Grid Total	$MtCO_2e$	***0.05***	***0.04***	***0.03***	***0.03***	***0.02***
Non-domestic Total			$MtCO_2e$	**2.61**	**1.86**	**1.40**	**1.21**	**1.12**
Industrial		Chemicals	$MtCO_2e$	*1.58*	*1.12*	*0.87*	*0.71*	*0.59*
		Metals and Minerals	$MtCO_2e$	*0.33*	*0.23*	*0.17*	*0.12*	*0.10*
		Refineries and Other Energy Industry	$MtCO_2e$	*5.38*	*4.42*	*3.89*	*3.51*	*3.25*
		Other	$MtCO_2e$	*6.31*	*5.03*	*4.06*	*3.28*	*2.68*
Industry Total			$MtCO_2e$	**13.60**	**10.80**	**9.00**	**7.62**	**6.62**
Total GHG Emissions for Heating and Cooling in Scotland			$MtCO_2e$	**26.62**	**20.07**	**16.02**	**13.43**	**11.76**

Table 40. Cost Summary: OPEX, Reference Scenario

Geography			Units	2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	*1,388*	*1,602*	*1,259*	*1,288*	*1,367*
		New-build	£m	*0*	*84*	*122*	*179*	*255*
		Urban Total	£m	***1,388***	***1,686***	***1,381***	***1,467***	***1,622***
	Rural On-Grid	Existing	£m	*366*	*418*	*335*	*341*	*361*
		New-build	£m	*0*	*12*	*17*	*22*	*28*
		Rural On-Grid Total	£m	***366***	***430***	***352***	***364***	***388***
	Rural Off-grid	Existing	£m	*292*	*453*	*375*	*370*	*375*
		New-build	£m	*0*	*10*	*14*	*18*	*22*
		Rural Off-Grid Total	£m	***292***	***463***	***389***	***388***	***397***
	Equipment Maintenance	Existing	£m	101	262	319	334	338
		New-build	£m	0	40	66	83	104
Domestic Total			£m	**2,147**	**2,880**	**2,507**	**2,635**	**2,849**
Non-domestic	Urban	Existing	£m	*368*	*406*	*380*	*412*	*443*
		New-build	£m	-	*33*	*65*	*112*	*184*
		Urban Total	£m	***368***	***439***	***446***	***524***	***627***
	Rural On-Grid	Existing	£m	*41*	*45*	*43*	*46*	*49*
		New-build	£m	-	*4*	*8*	*14*	*23*
		Rural On-Grid Total	£m	***41***	***49***	***51***	***60***	***72***
	Rural Off-grid	Existing	£m	*10*	*11*	*10*	*11*	*12*
		New-build	£m	-	*1*	*2*	*3*	*5*
		Rural Off-Grid Total	£m	***10***	***12***	***12***	***14***	***17***
	Equipment Maintenance	Existing	£m	***21***	***19***	***18***	***17***	***17***
		New-build	£m	**-**	***1***	***2***	***3***	***3***
Non-domestic Total			£m	**440**	**520**	**529**	**618**	**736**
Industry		CCS Costs	£m	-	-	-	-	-
		Fuel Purchase	£m	*1,981*	*2,589*	*2,605*	*2,915*	*3,268*
District Heating			£m	***5***	***67***	***177***	***348***	***566***
Scotland Total OPEX			£m	**4,573**	**6,057**	**5,818**	**6,516**	**7,419**

Table 41. Cost Summary: Average annual CAPEX, Reference Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	-	*632*	*531*	*492*	*465*
		New-build	£m	-	*208*	*404*	*451*	*522*
		Urban Total	£m	-	***840***	***935***	***943***	***987***
	Rural On-Grid	Existing	£m	-	*125*	*116*	*106*	*99*
		New-build	£m	-	*29*	*58*	*51*	*60*
		Rural On-Grid Total	£m	-	***154***	***174***	***157***	***158***
	Rural Off-grid	Existing	£m	-	*55*	*55*	*50*	*46*
		New-build	£m	-	*14*	*38*	*33*	*39*
		Rural Off-Grid Total	£m	-	***70***	***93***	***84***	***85***
		Cost of new-build offsets	£m	-	*0*	*0*	*50*	*146*
	Fabric Retrofit & New-build		£m	-	*322*	*588*	*749*	*750*
Domestic Total			£m	-	**1386**	**1790**	**1983**	**2127**
Non-domestic	Urban	Existing	£m	-	*28*	*27*	*24*	*5*
		New-build	£m	-	*5*	*6*	*7*	*8*
		Urban Total	£m	-	***33***	***33***	***31***	***13***
	Rural On-Grid	Existing	£m	-	*4*	*3*	*3*	*3*
		New-build	£m	-	*0*	*1*	*1*	*1*
		Rural On-Grid Total	£m	-	***4***	***4***	***4***	***4***
	Rural Off-grid	Existing	£m	-	*1*	*1*	*1*	*1*
		New-build	£m	-	*0*	*0*	*0*	*0*
		Rural Off-Grid Total	£m	-	***1***	***1***	***1***	***1***
		Cost of new-build offsets	£m	-	*0*	*0*	*13*	*33*
	Fabric Retrofit & New-build		£m	-	*89*	*539*	*786*	*921*
Non-domestic Total			£m	-	**127**	**577**	**835**	**972**
District Heating			£m	-	*33*	*75*	*97*	*101*
Scotland Total CAPEX (average annual value for preceding decade)			£m	-	**1546**	**2442**	**2914**	**3200**

Table 42. Heat Supply Technologies Delivered, Domestic Sector, Reference Scenario

Technologies delivered: Domestic		Existing stock, units				New-build stock, units			
Geography	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	616485	743965	724405	718668	55753	0	0	0
	Resistive heating	0	0	0	0	0	0	0	0
	Oil-fired boiler	0	57153	55650	55209	0	0	0	0
	Solid-fuel boiler	18856	0	0	0	0	0	0	0
	Biomass Boiler	43077	0	0	0	66373	151760	110057	128628
	Stirling engine µCHP	66786	0	0	0	17699	0	0	0
	Fuel-cell µCHP	66786	0	0	0	17699	0	0	0
	Air-source heat pump	133572	106874	92943	81285	17699	109917	149459	197716
	Ground-source heat pump	34122	105372	102602	101790	8850	46215	62841	83130
	District heating	52864	133862	130343	129310	20150	8613	92690	122617
Rural On-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	130084	157857	153451	151990	9274	0	0	0
	Resistive heating	0	0	0	0	0	0	0	0
	Oil-fired boiler	4661	2103	2044	2024	0	0	0	0
	Solid-fuel boiler	5073	2028	1972	1953	0	0	0	0
	Biomass Boiler	2537	4650	4520	4477	10047	22186	29193	38509
	Stirling engine µCHP	14092	4995	2500	167	2679	0	0	0
	Fuel-cell µCHP	14092	0	0	0	2679	0	0	0
	Air-source heat pump	32521	68033	66134	65504	2679	16069	0	0
	Ground-source heat pump	1613	3757	3652	3617	1340	6756	8890	11727
	District heating	0	0	0	0	0	0	0	0
Rural Off-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	0	0	0	0	0	0	0	0
	Resistive heating	73932	23654	22935	22498	0	0	0	0
	Oil-fired boiler	2844	1280	1241	1218	0	0	0	0
	Solid-fuel boiler	2730	1416	1373	1347	0	0	0	0
	Biomass Boiler	1774	3246	3147	3087	6700	14636	18959	24761
	Stirling engine µCHP	0	0	0	0	0	0	0	0
	Fuel-cell µCHP	0	0	0	0	0	0	0	0
	Air-source heat pump	22748	35621	34538	33879	1787	10600	0	0
	Ground-source heat pump	1228	2284	2215	2172	893	4457	5773	7540
	District heating	0	0	0	0	0	0	0	0

Table 43. Heat Supply Technologies Delivered, Non-Domestic Sector, Reference Scenario

Technologies delivered: Non-domestic		Existing stock, TWh of supply				New-build stock, TWh of new supply			
Geography	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	2.58	2.27	2.10	0.46	0.15	0.27	0.25	0.30
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.48	0.06	0.06	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.32	0.65	0.60	0.13	0.07	0.10	0.13	0.16
	Stirling engine µCHP	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.28	0.34	0.32	0.07	0.13	0.20	0.26	0.31
	Ground-source heat pump	0.03	0.05	0.04	0.01	0.02	0.03	0.03	0.04
	District heating	0.42	0.54	0.50	0.11	0.13	0.00	0.00	0.00
Rural On-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.27	0.25	0.23	0.22	0.00	0.03	0.03	0.03
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.06	0.03	0.03	0.03	0.00	0.00	0.00	0.00
	Biomass Boiler	0.05	0.09	0.09	0.08	0.00	0.01	0.02	0.02
	Stirling engine µCHP	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.03	0.04	0.03	0.03	0.00	0.03	0.03	0.04
	Ground-source heat pump	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	District heating	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Rural Off-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Resistive heating	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.04	0.03	0.03	0.03	0.01	0.00	0.00	0.00
	Solid-fuel boiler	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Biomass Boiler	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	Ground-source heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	District heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 44. Domestic retrofit measures delivered, Reference Scenario

		2020	2030	2040	2050
URBAN	Solid Walls Retrofitted	*88,815*	*160,835*	*215,233*	*257,414*
	Cavity Walls Retrofitted	*124,999*	*226,360*	*302,920*	*362,286*
	Floors Retrofitted	*245,722*	*444,979*	*595,480*	*712,181*
	Windows Retrofitted	*311,248*	*563,640*	*754,274*	*902,096*
	Lofts Retrofitted	*188,470*	*341,300*	*456,735*	*546,245*
	Ventilation Retrofitted	*245,722*	*444,979*	*595,480*	*712,181*
	Thermal Bridging Reduction	*245,722*	*444,979*	*595,480*	*712,181*
Rural On-Grid	Solid Walls Retrofitted	*10,855*	*19,707*	*26,370*	*31,524*
	Cavity Walls Retrofitted	*11,538*	*20,947*	*28,030*	*33,508*
	Floors Retrofitted	*51,850*	*94,129*	*125,958*	*150,573*
	Windows Retrofitted	*65,677*	*119,230*	*159,547*	*190,725*
	Lofts Retrofitted	*27,477*	*49,882*	*66,750*	*79,794*
	Ventilation Retrofitted	*51,850*	*94,129*	*125,958*	*150,573*
	Thermal Bridging Reduction	*51,850*	*94,129*	*125,958*	*150,573*
Rural Off-Grid	Solid Walls Retrofitted	*17,617*	*31,986*	*42,808*	*51,125*
	Cavity Walls Retrofitted	*8,773*	*15,929*	*21,318*	*25,461*
	Floors Retrofitted	*27,201*	*49,388*	*66,099*	*78,942*
	Windows Retrofitted	*34,455*	*62,559*	*83,725*	*99,993*
	Lofts Retrofitted	*29,937*	*54,356*	*72,746*	*86,882*
	Ventilation Retrofitted	*27,201*	*49,388*	*66,099*	*78,942*
	Thermal Bridging Reduction	*27,201*	*49,388*	*66,099*	*78,942*

Table 45. Heat Metrics Summary, Reference Scenario

		2010	2020	2030	2040	2050
Total Heat and Cooling Demand	TWh	96.13	90.35	84.86	79.92	76.14
Non-Electric Heat Demand	TWh	78.70	69.74	60.94	54.84	50.27
Total Fuel Consumption	TWh	99.93	89.80	81.06	74.84	70.15
Total Non-electric, Non-biomass Fuel Consumption	TWh	84.63	75.42	64.15	57.18	52.23
Biomass fuel consumption for heat	TWh	1.642	3.51	5.72	7.51	9.07
Renewable Heat Delivered	TWh	1.696	8.03	14.02	17.21	19.43

A1.3.2 Low Government Intervention, Low Uptake Scenario

Table 46. Heat Demands, Low GI, Low UT Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic *Space heating & DHW*	Urban	Existing	TWh	*25.69*	*23.60*	*23.05*	*22.11*	*20.78*
		New-build	TWh	*0.00*	*1.38*	*2.43*	*3.28*	*4.08*
		Urban Total	TWh	***25.69***	***24.98***	***25.48***	***25.39***	***24.86***
	Rural On-Grid	Existing	TWh	*6.81*	*6.18*	*6.01*	*5.74*	*5.37*
		New-build	TWh	*0.00*	*0.21*	*0.36*	*0.47*	*0.57*
		Rural On-Grid Total	TWh	***6.81***	***6.39***	***6.37***	***6.21***	***5.94***
	Rural Off-grid	Existing	TWh	*4.23*	*3.78*	*3.66*	*3.49*	*3.25*
		New-build	TWh	*0.00*	*0.17*	*0.28*	*0.37*	*0.44*
		Rural Off-Grid Total	TWh	***4.23***	***3.95***	***3.95***	***3.85***	***3.69***
Domestic Total			TWh	**36.73**	**35.32**	**35.79**	**35.45**	**34.49**
Non-domestic *Space heating & DHW*	Urban	Existing	TWh	*6.48*	*6.18*	*5.89*	*5.60*	*5.32*
		New-build	TWh	*0.00*	*0.51*	*0.84*	*1.04*	*1.29*
		Urban Total	TWh	***6.48***	***6.69***	***6.73***	***6.65***	***6.61***
	Rural On-Grid	Existing	TWh	*1.17*	*1.11*	*1.05*	*0.99*	*0.94*
		New-build	TWh	*0.00*	*0.06*	*0.10*	*0.12*	*0.15*
		Rural On-Grid Total	TWh	***1.17***	***1.17***	***1.15***	***1.11***	***1.09***
	Rural Off-grid	Existing	TWh	*0.11*	*0.11*	*0.10*	*0.10*	*0.09*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.03*
		Rural Off-Grid Total	TWh	***0.11***	***0.12***	***0.12***	***0.12***	***0.13***
Non-domestic Total			TWh	**7.75**	**7.98**	**8.00**	**7.88**	**7.82**
Industrial Total			TWh	**48.0**	**44.3**	**40.9**	**37.9**	**35.2**
	Catering & Cooking Demand		TWh	2.36	2.72	3.08	3.48	3.97
	Cooling Demand		TWh	1.27	1.43	1.63	1.95	2.35
	Total Heating and Cooling Demand for Scotland		TWh	**96.13**	**91.72**	**89.42**	**86.66**	**83.82**

Table 47. Total Energy Demand, Low GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	TWh	*29.09*	*25.29*	*24.88*	*24.06*	*22.28*
		New-build	TWh	*0.00*	*1.35*	*2.36*	*3.17*	*3.86*
		Urban Total	TWh	***29.09***	***26.64***	***27.24***	***27.23***	***26.14***
	Rural On-Grid	Existing	TWh	*7.65*	*6.57*	*6.01*	*5.64*	*5.28*
		New-build	TWh	*0.00*	*0.21*	*0.31*	*0.38*	*0.51*
		Rural On-Grid Total	TWh	***7.65***	***6.79***	***6.32***	***6.02***	***5.78***
	Rural Off-grid	Existing	TWh	*4.54*	*3.68*	*3.27*	*2.93*	*2.61*
		New-build	TWh	*0.00*	*0.17*	*0.24*	*0.29*	*0.39*
		Rural Off-Grid Total	TWh	***4.54***	***3.85***	***3.51***	***3.22***	***3.00***
Domestic Total			TWh	**41.27**	**37.28**	**37.08**	**36.48**	**34.92**
Non-domestic	Urban	Existing	TWh	*9.47*	*7.92*	*7.39*	*6.96*	*6.61*
		New-build	TWh	*0.00*	*0.59*	*1.07*	*1.47*	*1.98*
		Urban Total	TWh	***9.47***	***8.51***	***8.46***	***8.43***	***8.59***
	Rural On-Grid	Existing	TWh	*1.03*	*0.87*	*0.81*	*0.76*	*0.72*
		New-build	TWh	*0.00*	*0.08*	*0.13*	*0.18*	*0.24*
		Rural On-Grid Total	TWh	***1.03***	***0.95***	***0.94***	***0.94***	***0.96***
	Rural Off-grid	Existing	TWh	*0.15*	*0.14*	*0.13*	*0.12*	*0.12*
		New-build	TWh	*0.00*	*0.01*	*0.03*	*0.04*	*0.05*
		Rural Off-Grid Total	TWh	***0.15***	***0.15***	***0.16***	***0.16***	***0.17***
Non-domestic Total			TWh	**10.65**	**9.61**	**9.56**	**9.54**	**9.72**
Industrial		Chemicals	TWh	*6.0*	*5.3*	*4.6*	*4.0*	*3.5*
		Metals and Minerals	TWh	*1.0*	*0.9*	*0.8*	*0.7*	*0.6*
		Refineries and Other Energy Industry	TWh	*18.5*	*18.0*	*17.6*	*17.2*	*16.7*
		Other	TWh	*22.5*	*20.1*	*17.9*	*16.0*	*14.3*
Industry Total			TWh	**48.01**	**44.28**	**40.92**	**37.91**	**35.19**
Total Energy Demand for Heating and Cooling in Scotland			TWh	**99.93**	**91.17**	**87.56**	**83.92**	**79.83**

Table 48. GHG Emissions Summary, Low GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	$MtCO_2e$	*6.91*	*5.08*	*4.83*	*4.61*	*4.15*
		New-build	$MtCO_2e$	*0.00*	*0.26*	*0.41*	*0.40*	*0.40*
		Urban Total	$MtCO_2e$	***6.91***	***5.34***	***5.24***	***5.01***	***4.55***
	Rural On-Grid	Existing	$MtCO_2e$	*1.96*	*1.42*	*1.22*	*1.10*	*1.02*
		New-build	$MtCO_2e$	*0.00*	*0.03*	*0.03*	*0.02*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***1.96***	***1.46***	***1.25***	***1.12***	***1.03***
	Rural Off-grid	Existing	$MtCO_2e$	*1.55*	*0.87*	*0.49*	*0.27*	*0.17*
		New-build	$MtCO_2e$	*0.00*	*0.02*	*0.02*	*0.01*	*0.01*
		Rural Off-Grid Total	$MtCO_2e$	***1.55***	***0.89***	***0.51***	***0.29***	***0.18***
Domestic Total			$MtCO_2e$	**10.41**	**7.69**	**7.00**	**6.42**	**5.76**
Non-domestic	Urban	Existing	$MtCO_2e$	*2.30*	*1.58*	*1.28*	*1.14*	*1.08*
		New-build	$MtCO_2e$	*0.00*	*0.05*	*0.10*	*0.09*	*0.09*
		Urban Total	$MtCO_2e$	***2.30***	***1.63***	***1.38***	***1.24***	***1.16***
	Rural On-Grid	Existing	$MtCO_2e$	*0.26*	*0.18*	*0.16*	*0.14*	*0.13*
		New-build	$MtCO_2e$	*0.00*	*0.01*	*0.02*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***0.26***	***0.20***	***0.17***	***0.16***	***0.15***
	Rural Off-grid	Existing	$MtCO_2e$	*0.05*	*0.04*	*0.03*	*0.03*	*0.03*
		New-build	$MtCO_2e$	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Rural Off-Grid Total	$MtCO_2e$	***0.05***	***0.04***	***0.04***	***0.03***	***0.03***
Non-domestic Total			$MtCO_2e$	**2.61**	**1.87**	**1.59**	**1.43**	**1.34**
Industrial		Chemicals	$MtCO_2e$	*1.58*	*1.13*	*0.89*	*0.74*	*0.63*
		Metals and Minerals	$MtCO_2e$	*0.33*	*0.23*	*0.18*	*0.15*	*0.13*
		Refineries and Other Energy Industry	$MtCO_2e$	*5.38*	*4.50*	*4.09*	*3.83*	*3.68*
		Other	$MtCO_2e$	*6.31*	*5.22*	*4.51*	*3.96*	*3.51*
Industry Total			$MtCO_2e$	**13.60**	**11.09**	**9.67**	**8.67**	**7.95**
Total GHG Emissions for Heating and Cooling in Scotland			$MtCO_2e$	**26.62**	**20.65**	**18.26**	**16.52**	**15.05**

Table 49. Cost Summary: OPEX, Low GI, Low UT Scenario

Geography			Units	2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	*1,388*	*1,662*	*1,431*	*1,571*	*1,748*
		New-build	£m	*0*	*90*	*141*	*219*	*318*
		Urban Total	£m	***1,388***	***1,752***	***1,572***	***1,790***	***2,066***
	Rural On-Grid	Existing	£m	*366*	*434*	*381*	*421*	*468*
		New-build	£m	*0*	*13*	*21*	*29*	*55*
		Rural On-Grid Total	£m	***366***	***447***	***402***	***450***	***523***
	Rural Off-grid	Existing	£m	*292*	*471*	*460*	*516*	*570*
		New-build	£m	*0*	*10*	*16*	*23*	*43*
		Rural Off-Grid Total	£m	***292***	***481***	***476***	***539***	***613***
	Equipment Maintenance	Existing	£m	101	262	339	363	356
		New-build	£m	0	40	62	84	111
Domestic Total			£m	**2,147**	**2,981**	**2,851**	**3,227**	**3,669**
Non-domestic	Urban	Existing	£m	*368*	*409*	*388*	*428*	*464*
		New-build	£m	*-*	*33*	*65*	*114*	*189*
		Urban Total	£m	***368***	***441***	***453***	***542***	***652***
	Rural On-Grid	Existing	£m	*41*	*45*	*43*	*47*	*51*
		New-build	£m	*-*	*4*	*8*	*14*	*23*
		Rural On-Grid Total	£m		***41***	***50***	***51***	***61***
	Rural Off-grid	Existing	£m	*10*	*11*	*10*	*11*	*12*
		New-build	£m	*-*	*1*	*2*	*3*	*5*
		Rural Off-Grid Total	£m	***10***	***12***	***12***	***14***	***17***
	Equipment Maintenance	Existing	£m	***21***	***19***	***17***	***16***	***17***
		New-build	£m	***-***	***1***	***2***	***3***	***3***
Non-domestic Total			£m	**440**	**523**	**535**	**635**	**764**
Industry		CCS Costs	£m	*-*	*-*	*-*	*-*	*-*
		Fuel Purchase	£m	*1,981*	*2,577*	*2,594*	*2,896*	*3,241*
District Heating			£m	***5***	***69***	***194***	***381***	***623***
Scotland Total OPEX			£m	**4,573**	**6,150**	**6,175**	**7,139**	**8,298**

Table 50. Cost Summary: Average annual CAPEX, Low GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	-	*632*	*419*	*399*	*419*
		New-build	£m	-	*208*	*338*	*428*	*516*
		Urban Total	£m	-	***840***	***756***	***827***	***935***
	Rural On-Grid	Existing	£m	-	*125*	*95*	*89*	*83*
		New-build	£m	-	*29*	*43*	*51*	*50*
		Rural On-Grid Total	£m	-	***154***	***138***	***139***	***134***
	Rural Off-grid	Existing	£m	-	*55*	*48*	*44*	*41*
		New-build	£m	-	*14*	*28*	*33*	*33*
		Rural Off-Grid Total	£m	-	***70***	***76***	***77***	***74***
		Cost of new-build offsets	£m	-	*0*	*0*	*103*	*261*
	Fabric Retrofit & New-build		£m	-	*286*	*479*	*506*	*440*
Domestic Total			£m	-	**1350**	**1450**	**1653**	**1843**
Non-domestic	Urban	Existing	£m	-	*28*	*24*	*21*	*5*
		New-build	£m	-	*5*	*6*	*6*	*8*
		Urban Total	£m	-	***33***	***29***	***28***	***12***
	Rural On-Grid	Existing	£m	-	*4*	*3*	*3*	*3*
		New-build	£m	-	*0*	*1*	*1*	*1*
		Rural On-Grid Total	£m	-	***4***	***4***	***4***	***4***
	Rural Off-grid	Existing	£m	-	*1*	*1*	*1*	*1*
		New-build	£m	-	*0*	*0*	*0*	*0*
		Rural Off-Grid Total	£m	-	***1***	***1***	***1***	***1***
		Cost of new-build offsets	£m	-	*0*	*1*	*34*	*76*
	Fabric Retrofit & New-build		£m	-	*89*	*539*	*786*	*921*
Non-domestic Total			£m	-	**127**	**573**	**852**	**1013**
District Heating			£m	-	*34*	*85*	*107*	*113*
Scotland Total CAPEX (average annual value for preceding decade)			£m	-	**1511**	**2108**	**2612**	**2969**

Table 51. Heat Supply Technologies Delivered, Domestic Sector, Low GI, Low UT Scenario

Technologies delivered: Domestic		Existing stock, units				New-build stock, units			
	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	616485	901775	901040	903730	55753	0	0	0
	Resistive heating	0	0	0	0	0	0	23849	14158
	Oil-fired boiler	0	74547	74486	16913	0	0	0	0
	Solid-fuel boiler	18856	0	0	0	0	0	0	0
	Biomass Boiler	43077	0	0	0	66373	112415	156553	208386
	Stirling engine µCHP	66786	0	0	0	17699	0	0	0
	Fuel-cell µCHP	66786	0	0	0	17699	0	0	0
	Air-source heat pump	133572	0	0	0	17699	74943	104369	138924
	Ground-source heat pump	34122	57490	46032	92632	8850	37472	52184	69462
	District heating	52864	113413	113321	113659	20150	60080	83669	111371
Rural On-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	130084	191342	188262	187436	9274	0	0	0
	Resistive heating	0	0	0	0	0	0	0	18902
	Oil-fired boiler	4661	2743	2698	2687	0	0	0	0
	Solid-fuel boiler	5073	0	0	0	0	0	0	0
	Biomass Boiler	2537	0	0	0	10047	16434	22041	28353
	Stirling engine µCHP	14092	0	0	0	2679	0	0	0
	Fuel-cell µCHP	14092	0	0	0	2679	0	0	0
	Air-source heat pump	32521	46043	42917	40379	2679	10956	14694	0
	Ground-source heat pump	1613	3295	3242	3228	1340	5478	7347	9451
	District heating	0	0	0	0	0	0	0	0
Rural Off-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	0	0	0	0	0	0	0	0
	Resistive heating	73932	33394	32655	32200	0	0	0	12154
	Oil-fired boiler	2844	1670	1633	1610	0	0	0	0
	Solid-fuel boiler	2730	1603	1567	1546	0	0	0	0
	Biomass Boiler	1774	2404	2351	2318	6700	10841	14314	18231
	Stirling engine µCHP	0	0	0	0	0	0	0	0
	Fuel-cell µCHP	0	0	0	0	0	0	0	0
	Air-source heat pump	22748	27829	27213	26834	1787	7228	9542	0
	Ground-source heat pump	1228	2004	1959	1932	893	3614	4771	6077
	District heating	0	0	0	0	0	0	0	0

Table 52. Heat Supply Technologies Delivered, Non-Domestic Sector, Low GI, Low UT Scenario

Technologies delivered: Non-domestic		Existing stock, TWh of supply				New-build stock, TWh of new supply			
Geography	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	2.58	2.56	2.40	0.51	0.15	0.30	0.36	0.44
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.48	0.29	0.27	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.32	0.30	0.28	0.06	0.07	0.05	0.06	0.08
	Stirling engine µCHP	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.28	0.31	0.30	0.06	0.13	0.19	0.24	0.30
	Ground-source heat pump	0.03	0.04	0.04	0.01	0.02	0.02	0.03	0.04
	District heating	0.42	0.44	0.42	0.09	0.13	0.05	0.00	0.00
Rural On-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.27	0.28	0.26	0.25	0.00	0.04	0.04	0.05
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.06	0.06	0.05	0.05	0.00	0.00	0.00	0.00
	Biomass Boiler	0.05	0.04	0.04	0.04	0.00	0.01	0.01	0.01
	Stirling engine µCHP	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.04
	Ground-source heat pump	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01
	District heating	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Rural Off-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Resistive heating	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.04	0.04	0.04	0.04	0.01	0.01	0.01	0.01
	Solid-fuel boiler	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Biomass Boiler	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01
	Ground-source heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	District heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 53. Domestic retrofit measures delivered, Low GI, Low UT Scenario

		2020	2030	2040	2050
Urban	Solid Walls Retrofitted	*88,815*	*109,691*	*129,193*	*147,483*
	Cavity Walls Retrofitted	*124,999*	*154,379*	*181,827*	*207,568*
	Floors Retrofitted	*245,722*	*303,478*	*357,434*	*408,037*
	Windows Retrofitted	*311,248*	*384,405*	*452,750*	*516,847*
	Lofts Retrofitted	*188,470*	*232,769*	*274,154*	*312,966*
	Ventilation Retrofitted	*245,722*	*303,478*	*357,434*	*408,037*
	Thermal Bridging Reduction	*245,722*	*303,478*	*357,434*	*408,037*
Rural On-Grid	Solid Walls Retrofitted	*10,855*	*13,421*	*15,780*	*17,978*
	Cavity Walls Retrofitted	*11,538*	*14,265*	*16,773*	*19,109*
	Floors Retrofitted	*51,850*	*64,105*	*75,374*	*85,872*
	Windows Retrofitted	*65,677*	*81,199*	*95,474*	*108,771*
	Lofts Retrofitted	*27,477*	*33,971*	*39,943*	*45,507*
	Ventilation Retrofitted	*51,850*	*64,105*	*75,374*	*85,872*
	Thermal Bridging Reduction	*51,850*	*64,105*	*75,374*	*85,872*
Rural Off-Grid	Solid Walls Retrofitted	*17,617*	*21,781*	*25,591*	*29,109*
	Cavity Walls Retrofitted	*8,773*	*10,847*	*12,744*	*14,496*
	Floors Retrofitted	*27,201*	*33,632*	*39,514*	*44,947*
	Windows Retrofitted	*34,455*	*42,601*	*50,051*	*56,933*
	Lofts Retrofitted	*29,937*	*37,015*	*43,488*	*49,468*
	Ventilation Retrofitted	*27,201*	*33,632*	*39,514*	*44,947*
	Thermal Bridging Reduction	*27,201*	*33,632*	*39,514*	*44,947*

Table 54. Heat Metrics Summary, Low GI, Low UT Scenario

		2010	2020	2030	2040	2050
Total Heat and Cooling Demand	TWh	96.13	91.72	89.42	86.66	83.82
Non-Electric Heat Demand	TWh	78.70	72.22	69.74	66.83	63.03
Total Fuel Consumption	TWh	99.93	91.21	87.62	83.99	79.83
Total Non-electric, Non-biomass Fuel Consumption	TWh	84.63	78.05	74.19	70.71	66.71
Biomass fuel consumption for heat	TWh	1.642	2.96	4.16	5.47	6.78
Renewable Heat Delivered	TWh	1.696	7.61	10.58	13.05	15.73

A1.3.3 Low Government Intervention, High Uptake Scenario

Table 55. Heat Demands, Low GI, High UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic *Space heating & DHW*	Urban	Existing	TWh	*25.69*	*22.35*	*17.91*	*15.24*	*13.67*
		New-build	TWh	*0.00*	*1.31*	*2.13*	*2.68*	*3.24*
		Urban Total	TWh	***25.69***	***23.66***	***20.04***	***17.93***	***16.91***
	Rural On-Grid	Existing	TWh	*6.81*	*5.84*	*4.53*	*3.79*	*3.37*
		New-build	TWh	*0.00*	*0.20*	*0.31*	*0.38*	*0.45*
		Rural On-Grid Total	TWh	***6.81***	***6.04***	***4.85***	***4.17***	***3.82***
	Rural Off-grid	Existing	TWh	*4.23*	*3.57*	*2.68*	*2.19*	*1.94*
		New-build	TWh	*0.00*	*0.16*	*0.25*	*0.30*	*0.35*
		Rural Off-Grid Total	TWh	***4.23***	***3.73***	***2.92***	***2.49***	***2.29***
Domestic Total			TWh	**36.73**	**33.43**	**27.81**	**24.59**	**23.02**
Non-domestic *Space heating & DHW*	Urban	Existing	TWh	*6.48*	*6.10*	*5.73*	*5.37*	*5.02*
		New-build	TWh	*0.00*	*0.51*	*0.81*	*0.98*	*1.16*
		Urban Total	TWh	***6.48***	***6.60***	***6.54***	***6.35***	***6.19***
	Rural On-Grid	Existing	TWh	*1.17*	*1.09*	*1.02*	*0.95*	*0.88*
		New-build	TWh	*0.00*	*0.06*	*0.09*	*0.11*	*0.14*
		Rural On-Grid Total	TWh	***1.17***	***1.15***	***1.11***	***1.06***	***1.02***
	Rural Off-grid	Existing	TWh	*0.11*	*0.11*	*0.10*	*0.09*	*0.09*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.02*	*0.03*
		Rural Off-Grid Total	TWh	***0.11***	***0.12***	***0.12***	***0.12***	***0.12***
Non-domestic Total			TWh	**7.75**	**7.87**	**7.77**	**7.53**	**7.33**
Industrial Total			TWh	**48.0**	**44.3**	**40.9**	**37.9**	**35.2**
	Catering & Cooking Demand		TWh	2.36	2.72	3.07	3.47	3.93
	Cooling Demand		TWh	1.27	1.41	1.59	1.86	2.20
	Total Heating and Cooling Demand for Scotland		TWh	**96.13**	**89.71**	**81.16**	**75.35**	**71.67**

Table 56. Total Energy Demand, Low GI, High UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	TWh	*29.09*	*23.98*	*16.14*	*13.01*	*11.49*
		New-build	TWh	*0.00*	*1.28*	*1.53*	*1.75*	*2.02*
		Urban Total	TWh	***29.09***	***25.26***	***17.67***	***14.76***	***13.51***
	Rural On-Grid	Existing	TWh	*7.65*	*6.22*	*4.18*	*3.32*	*2.90*
		New-build	TWh	*0.00*	*0.20*	*0.19*	*0.29*	*0.37*
		Rural On-Grid Total	TWh	***7.65***	***6.43***	***4.37***	***3.62***	***3.27***
	Rural Off-grid	Existing	TWh	*4.54*	*3.49*	*2.19*	*1.56*	*1.23*
		New-build	TWh	*0.00*	*0.16*	*0.15*	*0.23*	*0.29*
		Rural Off-Grid Total	TWh	***4.54***	***3.65***	***2.33***	***1.79***	***1.52***
Domestic Total			TWh	**41.27**	**35.34**	**24.37**	**20.16**	**18.30**
Non-domestic	Urban	Existing	TWh	*9.47*	*7.81*	*7.38*	*6.93*	*6.45*
		New-build	TWh	*0.00*	*0.58*	*0.99*	*1.34*	*1.77*
		Urban Total	TWh	***9.47***	***8.39***	***8.37***	***8.26***	***8.22***
	Rural On-Grid	Existing	TWh	*1.03*	*0.86*	*0.77*	*0.72*	*0.67*
		New-build	TWh	*0.00*	*0.08*	*0.12*	*0.16*	*0.22*
		Rural On-Grid Total	TWh	***1.03***	***0.94***	***0.89***	***0.88***	***0.88***
	Rural Off-grid	Existing	TWh	*0.15*	*0.14*	*0.13*	*0.12*	*0.11*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.04*
		Rural Off-Grid Total	TWh	***0.15***	***0.15***	***0.15***	***0.15***	***0.15***
Non-domestic Total			TWh	**10.65**	**9.48**	**9.41**	**9.30**	**9.26**
Industrial		Chemicals	TWh	*6.0*	*5.3*	*4.6*	*4.0*	*3.5*
		Metals and Minerals	TWh	*1.0*	*0.9*	*0.8*	*0.7*	*0.6*
		Refineries and Other Energy Industry	TWh	*18.5*	*18.0*	*17.6*	*17.2*	*16.7*
		Other	TWh	*22.5*	*20.1*	*17.9*	*16.0*	*14.3*
Industry Total			TWh	**48.01**	**44.28**	**40.92**	**37.91**	**35.19**
Total Energy Demand for Heating and Cooling in Scotland			TWh	**99.93**	**89.10**	**74.70**	**67.36**	**62.75**

Table 57. GHG Emissions Summary, Low GI, High UT Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic	Urban	Existing	$MtCO_2e$	*6.91*	*4.82*	*2.78*	*1.96*	*1.62*
		New-build	$MtCO_2e$	*0.00*	*0.25*	*0.24*	*0.23*	*0.23*
		Urban Total	$MtCO_2e$	***6.91***	***5.06***	***3.02***	***2.19***	***1.84***
	Rural On-Grid	Existing	$MtCO_2e$	*1.96*	*1.35*	*0.82*	*0.61*	*0.52*
		New-build	$MtCO_2e$	*0.00*	*0.03*	*0.01*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***1.96***	***1.38***	***0.84***	***0.62***	***0.52***
	Rural Off-grid	Existing	$MtCO_2e$	*1.55*	*0.83*	*0.34*	*0.16*	*0.09*
		New-build	$MtCO_2e$	*0.00*	*0.02*	*0.01*	*0.01*	*0.01*
		Rural Off-Grid Total	$MtCO_2e$	***1.55***	***0.85***	***0.35***	***0.16***	***0.10***
Domestic Total			$MtCO_2e$	**10.41**	**7.29**	**4.20**	**2.97**	**2.46**
Non-domestic	Urban	Existing	$MtCO_2e$	*2.30*	*1.56*	*0.97*	*0.79*	*0.72*
		New-build	$MtCO_2e$	*0.00*	*0.05*	*0.06*	*0.05*	*0.04*
		Urban Total	$MtCO_2e$	***2.30***	***1.61***	***1.03***	***0.84***	***0.76***
	Rural On-Grid	Existing	$MtCO_2e$	*0.26*	*0.18*	*0.10*	*0.08*	*0.07*
		New-build	$MtCO_2e$	*0.00*	*0.01*	*0.01*	*0.01*	*0.00*
		Rural On-Grid Total	$MtCO_2e$	***0.26***	***0.19***	***0.11***	***0.09***	***0.08***
	Rural Off-grid	Existing	$MtCO_2e$	*0.05*	*0.04*	*0.02*	*0.01*	*0.01*
		New-build	$MtCO_2e$	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Rural Off-Grid Total	$MtCO_2e$	***0.05***	***0.04***	***0.02***	***0.01***	***0.01***
Non-domestic Total			$MtCO_2e$	**2.61**	**1.84**	**1.16**	**0.94**	**0.84**
Industrial		Chemicals	$MtCO_2e$	*1.58*	*1.08*	*0.79*	*0.59*	*0.45*
		Metals and Minerals	$MtCO_2e$	*0.33*	*0.22*	*0.15*	*0.10*	*0.06*
		Refineries and Other Energy Industry	$MtCO_2e$	*5.38*	*4.21*	*3.46*	*2.87*	*2.42*
		Other	$MtCO_2e$	*6.31*	*4.84*	*3.70*	*2.78*	*2.07*
Industry Total			$MtCO_2e$	**13.60**	**10.35**	**8.10**	**6.34**	**5.00**
Total GHG Emissions for Heating and Cooling in Scotland			$MtCO_2e$	**26.62**	**19.47**	**13.46**	**10.24**	**8.31**

Table 58. Cost Summary: OPEX, Low GI, High UT Scenario

Geography			Units	2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	*1,388*	*1,573*	*1,138*	*1,129*	*1,203*
		New-build	£m	*0*	*85*	*110*	*154*	*214*
		Urban Total	£m	***1,388***	***1,658***	***1,248***	***1,283***	***1,417***
	Rural On-Grid	Existing	£m	*366*	*410*	*304*	*300*	*318*
		New-build	£m	*0*	*12*	*16*	*19*	*22*
		Rural On-Grid Total	£m	***366***	***423***	***320***	***319***	***340***
	Rural Off-grid	Existing	£m	*292*	*445*	*289*	*247*	*234*
		New-build	£m	*0*	*10*	*13*	*15*	*18*
		Rural Off-Grid Total	£m	***292***	***455***	***302***	***262***	***251***
	Equipment Maintenance	Existing	£m	101	262	280	283	282
		New-build	£m	0	40	58	69	86
Domestic Total			£m	**2,147**	**2,837**	**2,208**	**2,216**	**2,377**
Non-domestic	Urban	Existing	£m	*368*	*403*	*378*	*399*	*418*
		New-build	£m	-	*32*	*65*	*111*	*177*
		Urban Total	£m	***368***	***435***	***444***	***509***	***595***
	Rural On-Grid	Existing	£m	*41*	*45*	*43*	*45*	*47*
		New-build	£m	-	*4*	*8*	*14*	*22*
		Rural On-Grid Total	£m	***41***	***49***	***51***	***59***	***69***
	Rural Off-grid	Existing	£m	*10*	*11*	*10*	*9*	*10*
		New-build	£m	-	*1*	*2*	*3*	*5*
		Rural Off-Grid Total	£m	***10***	***12***	***11***	***12***	***14***
	Equipment Maintenance	Existing	£m	***21***	***18***	***20***	***20***	***19***
		New-build	£m	-	***1***	***2***	***3***	***4***
Non-domestic Total			£m	**440**	**515**	**529**	**603**	**700**
Industry		CCS Costs	£m	-	-	-	-	-
		Fuel Purchase	£m	*1,981*	*2,553*	*2,511*	*2,752*	*3,018*
District Heating			£m	***5***	***66***	***190***	***373***	***607***
Scotland Total OPEX			£m	**4,573**	**5,971**	**5,438**	**5,944**	**6,701**

Table 59. Cost Summary: Average annual CAPEX, Low GI, High UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	-	*632*	*721*	*640*	*593*
		New-build	£m	-	*208*	*441*	*465*	*526*
		Urban Total	£m	**-**	***840***	***1162***	***1106***	***1118***
	Rural On-Grid	Existing	£m	-	*125*	*151*	*134*	*122*
		New-build	£m	-	*29*	*64*	*72*	*86*
		Rural On-Grid Total	£m	**-**	***154***	***215***	***206***	***208***
	Rural Off-grid	Existing	£m	-	*55*	*68*	*61*	*56*
		New-build	£m	-	*14*	*42*	*47*	*56*
		Rural Off-Grid Total	£m	**-**	***70***	***110***	***108***	***111***
		Cost of new-build offsets	£m	**-**	*0*	*0*	*3*	*23*
	Fabric retrofit & new-build		£m	**-**	*286*	*892*	*1077*	*1066*
Domestic Total			£m	**-**	**1350**	**2379**	**2500**	**2527**
Non-domestic	Urban	Existing	£m	-	*28*	*29*	*26*	*6*
		New-build	£m	-	*5*	*8*	*9*	*9*
		Urban Total	£m	**-**	***33***	***37***	***35***	***15***
	Rural On-Grid	Existing	£m	-	*4*	*4*	*4*	*3*
		New-build	£m	-	*0*	*1*	*1*	*1*
		Rural On-Grid Total	£m	**-**	***4***	***5***	***5***	***4***
	Rural Off-grid	Existing	£m	-	*1*	*1*	*1*	*0*
		New-build	£m	-	*0*	*0*	*0*	*0*
		Rural Off-Grid Total	£m	-	***1***	***1***	***1***	***1***
		Cost of new-build offsets	£m	-	*0*	*0*	*0*	*0*
	Fabric retrofit & new-build		£m	**-**	*90*	*539*	*786*	*921*
Non-domestic Total			£m	**-**	**127**	**582**	**826**	**941**
District Heating			£m	**-**	*33*	*83*	*104*	*109*
Scotland Total CAPEX (average annual value for preceding decade)			£m	**-**	**1510**	**3044**	**3431**	**3578**

Table 60.Heat Supply Technologies Delivered, Domestic Sector, Low GI, High UT Scenario

Technologies delivered: Domestic		Existing stock, units				New-build stock, units			
	Technology	2020	2030	2040	2050	2020	2030	2040	2050
URBAN	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	616485	450888	423943	416094	55753	0	0	0
	Resistive heating	0	0	0	0	0	0	0	0
	Oil-fired boiler	0	24849	23364	22931	0	0	0	0
	Solid-fuel boiler	18856	0	0	0	0	0	0	0
	Biomass Boiler	43077	0	0	0	66373	79185	0	0
	Stirling engine µCHP	66786	0	0	0	17699	0	0	0
	Fuel-cell µCHP	66786	0	0	0	17699	0	0	0
	Air-source heat pump	133572	370246	337382	320701	17699	174868	215486	266601
	Ground-source heat pump	34122	129405	121672	119419	8850	62453	80933	106869
	District heating	52864	171838	161569	158578	20150	0	107802	142349
Rural On-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	130084	95671	91583	90281	9274	0	0	0
	Resistive heating	0	0	0	0	0	0	0	0
	Oil-fired boiler	4661	914	875	863	0	0	0	0
	Solid-fuel boiler	5073	1531	1465	1444	0	0	0	0
	Biomass Boiler	2537	6888	6594	6500	10047	11196	41242	56393
	Stirling engine µCHP	14092	38134	34185	31435	2679	0	0	0
	Fuel-cell µCHP	14092	0	0	0	2679	0	0	0
	Air-source heat pump	32521	95671	91583	90281	2679	25564	0	0
	Ground-source heat pump	1613	4613	4416	4354	1340	9130	11456	15665
	District heating	0	0	0	0	0	0	0	0
Rural Off-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	0	0	0	0	0	0	0	0
	Resistive heating	73932	5566	5313	5163	0	0	0	0
	Oil-fired boiler	2844	557	531	516	0	0	0	0
	Solid-fuel boiler	2730	1069	1020	991	0	0	0	0
	Biomass Boiler	1774	4809	4591	4460	6700	7306	26781	36259
	Stirling engine µCHP	0	0	0	0	0	0	0	0
	Fuel-cell µCHP	0	0	0	0	0	0	0	0
	Air-source heat pump	22748	50092	47819	46463	1787	16864	0	0
	Ground-source heat pump	1228	2805	2678	2602	893	6023	7439	10072
	District heating	0	0	0	0	0	0	0	0

Table 61. Heat Supply Technologies Delivered, Non-domestic Sector, Low GI, High UT Scenario

Technologies delivered: Non-domestic		Existing stock, TWh of supply				New-build stock, TWh of new supply			
Geography	Technology	2020	2030	2040	2050	2020	2030	2040	2050
URBAN	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	2.58	1.75	1.61	0.36	0.15	0.12	0.06	0.06
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.32	1.31	1.21	0.27	0.07	0.20	0.25	0.30
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.28	0.04	0.04	0.01	0.13	0.23	0.28	0.33
	Ground-source heat pump	0.03	0.06	0.05	0.01	0.02	0.03	0.04	0.05
	District heating	0.42	0.73	0.67	0.15	0.13	0.00	0.00	0.00
Rural On-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.27	0.18	0.16	0.14	0.00	0.01	0.00	0.00
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.05	0.19	0.18	0.16	0.00	0.03	0.03	0.03
	Stirling engine µCHP	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.03	0.04	0.04	0.04	0.00	0.03	0.03	0.04
	Ground-source heat pump	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	District heating	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Rural Off-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Resistive heating	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.04	0.01	0.00	0.00	0.01	0.00	0.00	0.00
	Solid-fuel boiler	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.01	0.03	0.03	0.03	0.00	0.01	0.01	0.01
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	Ground-source heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	District heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 62. Domestic retrofit measures delivered, Low GI, Low UT Scenario

		2020	2030	2040	2050
URBAN	Solid Walls Retrofitted	*88,815*	*255,818*	*331,174*	*368,967*
	Cavity Walls Retrofitted	*124,999*	*360,040*	*466,097*	*519,287*
	Floors Retrofitted	*245,722*	*707,766*	*916,252*	*1,020,812*
	Windows Retrofitted	*311,248*	*896,504*	*1,160,585*	*1,293,029*
	Lofts Retrofitted	*188,470*	*542,859*	*702,768*	*782,967*
	Ventilation Retrofitted	*245,722*	*707,766*	*916,252*	*1,020,812*
	Thermal Bridging Reduction	*245,722*	*707,766*	*916,252*	*1,020,812*
Rural On-Grid	Solid Walls Retrofitted	*10,855*	*31,380*	*40,753*	*45,366*
	Cavity Walls Retrofitted	*11,538*	*33,355*	*43,317*	*48,221*
	Floors Retrofitted	*51,850*	*149,888*	*194,655*	*216,692*
	Windows Retrofitted	*65,677*	*189,858*	*246,563*	*274,477*
	Lofts Retrofitted	*27,477*	*79,431*	*103,155*	*114,833*
	Ventilation Retrofitted	*51,850*	*149,888*	*194,655*	*216,692*
	Thermal Bridging Reduction	*51,850*	*149,888*	*194,655*	*216,692*
Rural Off-Grid	Solid Walls Retrofitted	*17,617*	*50,936*	*66,278*	*73,819*
	Cavity Walls Retrofitted	*8,773*	*25,366*	*33,007*	*36,762*
	Floors Retrofitted	*27,201*	*78,649*	*102,340*	*113,983*
	Windows Retrofitted	*34,455*	*99,623*	*129,630*	*144,379*
	Lofts Retrofitted	*29,937*	*86,560*	*112,632*	*125,447*
	Ventilation Retrofitted	*27,201*	*78,649*	*102,340*	*113,983*
	Thermal Bridging Reduction	*27,201*	*78,649*	*102,340*	*113,983*

Table 63. Heat Metrics summary, Low GI, High UT Scenario

		2010	2020	2030	2040	2050
Total Heat and Cooling Demand	TWh	96.13	89.71	81.16	75.35	71.67
Non-Electric Heat Demand	TWh	78.70	67.72	51.48	43.22	37.72
Total Fuel Consumption	TWh	99.93	89.14	74.76	67.42	62.75
Total Non-electric, Non-biomass Fuel Consumption	TWh	84.63	73.33	53.31	43.90	38.00
Biomass fuel consumption for heat	TWh	1.642	4.82	9.24	12.35	14.83
Renewable Heat Delivered	TWh	1.696	9.29	20.53	25.34	28.66

A1.3.4 High Government Intervention, Low Uptake Scenario

Table 64. Heat Demands, High GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic *Space heating & DHW*	Urban	Existing	TWh	*25.69*	*23.60*	*23.05*	*22.12*	*20.80*
		New-build	TWh	*0.00*	*1.35*	*2.29*	*3.14*	*3.95*
		Urban Total	TWh	***25.69***	***24.95***	***25.33***	***25.26***	***24.75***
	Rural On-Grid	Existing	TWh	*6.81*	*6.18*	*6.01*	*5.75*	*5.38*
		New-build	TWh	*0.00*	*0.20*	*0.34*	*0.45*	*0.55*
		Rural On-Grid Total	TWh	***6.81***	***6.38***	***6.35***	***6.19***	***5.93***
	Rural Off-grid	Existing	TWh	*4.23*	*3.78*	*3.66*	*3.49*	*3.25*
		New-build	TWh	*0.00*	*0.16*	*0.27*	*0.35*	*0.42*
		Rural Off-Grid Total	TWh	***4.23***	***3.94***	***3.93***	***3.84***	***3.68***
Domestic Total			TWh	**36.73**	**35.28**	**35.61**	**35.29**	**34.36**
Non-domestic *Space heating & DHW*	Urban	Existing	TWh	*6.48*	*6.11*	*5.76*	*5.41*	*5.06*
		New-build	TWh	*0.00*	*0.51*	*0.84*	*1.04*	*1.29*
		Urban Total	TWh	***6.48***	***6.63***	***6.59***	***6.45***	***6.35***
	Rural On-Grid	Existing	TWh	*1.17*	*1.09*	*1.02*	*0.95*	*0.88*
		New-build	TWh	*0.00*	*0.06*	*0.10*	*0.12*	*0.15*
		Rural On-Grid Total	TWh	***1.17***	***1.15***	***1.12***	***1.07***	***1.03***
	Rural Off-grid	Existing	TWh	*0.11*	*0.11*	*0.10*	*0.09*	*0.09*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.03*
		Rural Off-Grid Total	TWh	***0.11***	***0.12***	***0.12***	***0.12***	***0.12***
Non-domestic Total			TWh	**7.75**	**7.90**	**7.83**	**7.64**	**7.50**
Industrial Total			TWh	**48.0**	**44.3**	**40.9**	**37.9**	**35.2**
	Catering & Cooking Demand		TWh	2.36	2.72	3.08	3.48	3.97
	Cooling Demand		TWh	1.27	1.43	1.63	1.95	2.35
	Total Heating and Cooling Demand for Scotland		TWh	**96.13**	**91.60**	**89.07**	**86.26**	**83.37**

Table 65. Total Energy Demand, High GI, Low UT Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic	Urban	Existing	TWh	*29.09*	*25.18*	*21.61*	*19.16*	*17.24*
		New-build	TWh	*0.00*	*1.31*	*1.94*	*2.46*	*2.95*
		Urban Total	TWh	***29.09***	***26.49***	***23.55***	***21.61***	***20.19***
	Rural On-Grid	Existing	TWh	*7.65*	*6.54*	*5.92*	*5.17*	*4.55*
		New-build	TWh	*0.00*	*0.21*	*0.29*	*0.36*	*0.49*
		Rural On-Grid Total	TWh	***7.65***	***6.75***	***6.21***	***5.54***	***5.04***
	Rural Off-grid	Existing	TWh	*4.54*	*3.73*	*3.30*	*2.95*	*2.63*
		New-build	TWh	*0.00*	*0.16*	*0.23*	*0.28*	*0.38*
		Rural Off-Grid Total	TWh	***4.54***	***3.89***	***3.53***	***3.23***	***3.01***
Domestic Total			TWh	**41.27**	**37.14**	**33.29**	**30.38**	**28.24**
Non-domestic	Urban	Existing	TWh	*9.47*	*7.96*	*7.29*	*6.61*	*6.01*
		New-build	TWh	*0.00*	*0.60*	*1.01*	*1.39*	*1.87*
		Urban Total	TWh	***9.47***	***8.56***	***8.31***	***8.00***	***7.88***
	Rural On-Grid	Existing	TWh	*1.03*	*0.87*	*0.79*	*0.72*	*0.65*
		New-build	TWh	*0.00*	*0.08*	*0.13*	*0.17*	*0.23*
		Rural On-Grid Total	TWh	***1.03***	***0.95***	***0.92***	***0.89***	***0.87***
	Rural Off-grid	Existing	TWh	*0.15*	*0.14*	*0.13*	*0.12*	*0.11*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.05*
		Rural Off-Grid Total	TWh	***0.15***	***0.15***	***0.15***	***0.15***	***0.15***
Non-domestic Total			TWh	**10.65**	**9.66**	**9.38**	**9.04**	**8.90**
Industrial		Chemicals	TWh	*6.0*	*5.3*	*4.6*	*4.0*	*3.5*
		Metals and Minerals	TWh	*1.0*	*0.9*	*0.8*	*0.7*	*0.6*
		Refineries and Other Energy Industry	TWh	*18.5*	*18.0*	*17.6*	*17.2*	*16.7*
		Other	TWh	*22.5*	*20.1*	*17.9*	*16.0*	*14.3*
Industry Total			TWh	**48.01**	**44.28**	**40.92**	**37.91**	**35.19**
Total Energy Demand for Heating and Cooling in Scotland			TWh	**99.93**	**91.07**	**83.60**	**77.32**	**72.33**

Table 66. GHG Emissions Summary, High GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	$MtCO_2e$	*6.91*	*4.94*	*3.58*	*2.12*	*1.21*
		New-build	$MtCO_2e$	*0.00*	*0.23*	*0.23*	*0.21*	*0.15*
		Urban Total	$MtCO_2e$	***6.91***	***5.17***	***3.81***	***2.33***	***1.36***
	Rural On-Grid	Existing	$MtCO_2e$	*1.96*	*1.39*	*1.17*	*0.79*	*0.50*
		New-build	$MtCO_2e$	*0.00*	*0.03*	*0.02*	*0.02*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***1.96***	***1.42***	***1.20***	***0.80***	***0.51***
	Rural Off-grid	Existing	$MtCO_2e$	*1.55*	*0.94*	*0.60*	*0.35*	*0.20*
		New-build	$MtCO_2e$	*0.00*	*0.02*	*0.02*	*0.01*	*0.01*
		Rural Off-Grid Total	$MtCO_2e$	***1.55***	***0.96***	***0.61***	***0.36***	***0.21***
Domestic Total			$MtCO_2e$	**10.41**	**7.55**	**5.62**	**3.49**	**2.09**
Non-domestic	Urban	Existing	$MtCO_2e$	*2.30*	*1.46*	*1.14*	*0.80*	*0.57*
		New-build	$MtCO_2e$	*0.00*	*0.07*	*0.07*	*0.06*	*0.04*
		Urban Total	$MtCO_2e$	***2.30***	***1.54***	***1.22***	***0.86***	***0.61***
	Rural On-Grid	Existing	$MtCO_2e$	*0.26*	*0.15*	*0.13*	*0.10*	*0.07*
		New-build	$MtCO_2e$	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***0.26***	***0.17***	***0.15***	***0.11***	***0.08***
	Rural Off-grid	Existing	$MtCO_2e$	*0.05*	*0.04*	*0.02*	*0.01*	*0.01*
		New-build	$MtCO_2e$	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Rural Off-Grid Total	$MtCO_2e$	***0.05***	***0.04***	***0.02***	***0.02***	***0.01***
Non-domestic Total			$MtCO_2e$	**2.61**	**1.74**	**1.39**	**0.99**	**0.70**
Industrial		Chemicals	$MtCO_2e$	*1.58*	*1.13*	*0.73*	*0.52*	*0.38*
		Metals and Minerals	$MtCO_2e$	*0.33*	*0.23*	*0.16*	*0.12*	*0.09*
		Refineries and Other Energy Industry	$MtCO_2e$	*5.38*	*4.50*	*3.13*	*2.43*	*1.86*
		Other	$MtCO_2e$	*6.31*	*5.22*	*4.40*	*3.81*	*3.34*
Industry Total			$MtCO_2e$	**13.60**	**11.09**	**8.42**	**6.88**	**5.67**
Total GHG Emissions for Heating and Cooling in Scotland			$MtCO_2e$	**26.62**	**20.38**	**15.43**	**11.37**	**8.45**

Table 67. Cost Summary: OPEX, High GI, Low UT Scenario

Geography			Units	2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	*1,388*	*1,513*	*1,443*	*2,209*	*2,825*
		New-build	£m	*0*	*78*	*131*	*277*	*461*
		Urban Total	£m	***1,388***	***1,591***	***1,573***	***2,486***	***3,285***
	Rural On-Grid	Existing	£m	*366*	*397*	*370*	*579*	*767*
		New-build	£m	*0*	*10*	*17*	*27*	*53*
		Rural On-Grid Total	£m	***366***	***407***	***387***	***606***	***820***
	Rural Off-grid	Existing	£m	*292*	*334*	*384*	*464*	*541*
		New-build	£m	*0*	*10*	*15*	*22*	*42*
		Rural Off-Grid Total	£m	***292***	***344***	***399***	***485***	***583***
	Equipment Maintenance	Existing	£m	101	258	252	236	225
		New-build	£m	0	40	62	84	111
Domestic Total			£m	**2,147**	**2,640**	**2,674**	**3,898**	**5,024**
Non-domestic	Urban	Existing	£m	*368*	*414*	*405*	*503*	*589*
		New-build	£m	-	*35*	*69*	*127*	*214*
		Urban Total	£m	***368***	***449***	***474***	***629***	***803***
	Rural On-Grid	Existing	£m	*41*	*47*	*46*	*57*	*67*
		New-build	£m	-	*4*	*8*	*15*	*26*
		Rural On-Grid Total	£m	***41***	***51***	***54***	***72***	***93***
	Rural Off-grid	Existing	£m	*10*	*11*	*11*	*12*	*13*
		New-build	£m	-	*1*	*2*	*3*	*6*
		Rural Off-Grid Total	£m	***10***	***12***	***13***	***16***	***19***
	Equipment Maintenance	Existing	£m	***21***	***21***	***19***	***17***	***15***
		New-build	£m	**-**	***2***	***2***	***2***	***3***
Non-domestic Total			£m	**440**	**535**	**563**	**736**	**933**
Industry		CCS Costs	£m	-	-	*76*	*109*	*138*
		Fuel Purchase	£m	*1,981*	*2,577*	*2,594*	*2,896*	*3,241*
District Heating			£m	***5***	***68***	***191***	***375***	***614***
Scotland Total OPEX			£m	**4,573**	**5,820**	**6,097**	**8,013**	**9,950**

Table 68. Cost Summary: Average annual CAPEX, High GI, Low UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	-	*619*	*464*	*506*	*474*
		New-build	£m	-	*208*	*338*	*428*	*516*
		Urban Total	£m	**-**	***826***	***802***	***934***	***990***
	Rural On-Grid	Existing	£m	-	*120*	*102*	*67*	*62*
		New-build	£m	-	*29*	*43*	*51*	*50*
		Rural On-Grid Total	£m	**-**	***149***	***145***	***118***	***113***
	Rural Off-grid	Existing	£m	-	*31*	*38*	*36*	*33*
		New-build	£m	-	*14*	*28*	*33*	*33*
		Rural Off-Grid Total	£m	**-**	***45***	***67***	***69***	***66***
		Cost of new-build offsets	£m	**-**	*5*	*68*	*40*	*4*
	Fabric retrofit & new-build		£m		*322*	*576*	*372*	*435*
Domestic Total			£m	**-**	**1347**	**1657**	**1532**	**1608**
Non-domestic	Urban	Existing	£m	-	*35*	*13*	*17*	*4*
		New-build	£m	-	*6*	*5*	*7*	*8*
		Urban Total	£m	**-**	***41***	***18***	***24***	***11***
	Rural On-Grid	Existing	£m	-	*4*	*1*	*2*	*2*
		New-build	£m	-	*0*	*1*	*1*	*1*
		Rural On-Grid Total	£m	**-**	***4***	***2***	***3***	***3***
	Rural Off-grid	Existing	£m	-	*0*	*0*	*0*	*0*
		New-build	£m	-	*0*	*0*	*0*	*0*
		Rural Off-Grid Total	£m	-	***1***	***0***	***0***	***0***
		Cost of new-build offsets	£m	**-**	*1*	*19*	*4*	*0*
	Fabric retrofit & new-build		£m	**-**	*91*	*540*	*788*	*922*
Non-domestic Total			£m	**-**	**138**	**580**	**818**	**937**
District Heating			£m	**-**	*35*	*83*	*106*	*113*
Scotland Total CAPEX (average annual value for preceding decade)			£m	**-**	**1520**	**2320**	**2456**	**2657**

Table 69. Heat supply technologies delivered, Domestic sector, High GI, Low UT Scenario

Technologies delivered: Domestic		Existing stock, units				New-build stock, units			
	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	616485	0	0	0	55753	0	0	0
	Resistive heating	0	0	286777	281237	0	0	23849	14158
	Oil-fired boiler	0	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	43077	58165	55491	54419	66373	112415	156553	208386
	Stirling engine µCHP	66786	0	0	0	17699	0	0	0
	Fuel-cell µCHP	66786	0	0	0	17699	0	0	0
	Air-source heat pump	133572	250493	238981	234364	17699	74943	104369	138924
	Ground-source heat pump	34122	92432	88184	86480	8850	37472	52184	69462
	District heating	52864	113413	108201	106111	20150	60080	83669	111371
Rural On-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	130084	183533	0	0	9274	0	0	0
	Resistive heating	0	0	62521	61349	0	0	0	18902
	Oil-fired boiler	0	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	2537	3444	3376	3313	10047	16434	22041	28353
	Stirling engine µCHP	14092	0	0	0	2679	0	0	0
	Fuel-cell µCHP	14092	0	0	0	2679	0	0	0
	Air-source heat pump	32521	53151	52101	51124	2679	10956	14694	0
	Ground-source heat pump	1613	3295	3230	3170	1340	5478	7347	9451
	District heating	0	0	0	0	0	0	0	0
Rural Off-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	0	0	0	0	0	0	0	0
	Resistive heating	0	33290	32575	32123	0	0	0	12154
	Oil-fired boiler	2844	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	1774	2397	2345	2313	6700	10841	14314	18231
	Stirling engine µCHP	0	0	0	0	0	0	0	0
	Fuel-cell µCHP	0	0	0	0	0	0	0	0
	Air-source heat pump	22748	27741	27146	26769	1787	7228	9542	0
	Ground-source heat pump	1228	1997	1955	1927	893	3614	4771	6077
	District heating	0	0	0	0	0	0	0	0

Table 70. Heat Supply Technologies Delivered, Non-domestic Sector, High GI, Low UT Scenario

Technologies delivered: Non-domestic		Existing stock, TWh of supply				New-build stock, TWh of new supply			
Geography	Technology	2020	2030	2040	2050	2020	2030	2040	2050
Urban	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	2.58	0.00	0.00	0.00	0.15	0.00	0.00	0.00
	Resistive heating	0.00	0.00	0.53	0.12	0.00	0.00	0.09	0.11
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.32	0.29	0.26	0.06	0.07	0.05	0.06	0.07
	Stirling engine µCHP	0.11	0.00	0.00	0.00	0.04	0.00	0.00	0.00
	Fuel-cell µCHP	0.56	0.00	0.00	0.00	0.04	0.00	0.00	0.00
	Air-source heat pump	0.28	0.31	0.28	0.06	0.13	0.20	0.23	0.28
	Ground-source heat pump	0.03	0.04	0.04	0.01	0.02	0.02	0.03	0.04
	District heating	0.42	0.44	0.40	0.09	0.05	0.07	0.09	0.11
Rural On-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.27	0.00	0.00	0.00	0.00	0.04	0.00	0.00
	Resistive heating	0.00	0.00	0.06	0.05	0.00	0.00	0.01	0.01
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.05	0.04	0.04	0.04	0.00	0.01	0.01	0.01
	Stirling engine µCHP	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.03	0.03	0.03	0.03	0.00	0.02	0.03	0.03
	Ground-source heat pump	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01
	District heating	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Rural Off-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Resistive heating	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01
	Ground-source heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	District heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 71. Domestic retrofit measures delivered, High GI, Low UT Scenario

		2020	2030	2040	2050
Urban	Solid Walls Retrofitted	*88,815*	*109,691*	*128,312*	*145,441*
	Cavity Walls Retrofitted	*124,999*	*154,379*	*180,587*	*204,694*
	Floors Retrofitted	*245,722*	*303,478*	*354,997*	*402,387*
	Windows Retrofitted	*311,248*	*384,405*	*449,663*	*509,690*
	Lofts Retrofitted	*188,470*	*232,769*	*272,284*	*308,632*
	Ventilation Retrofitted	*245,722*	*303,478*	*354,997*	*402,387*
	Thermal Bridging Reduction	*245,722*	*303,478*	*354,997*	*402,387*
Rural On-Grid	Solid Walls Retrofitted	*10,855*	*13,421*	*15,771*	*17,930*
	Cavity Walls Retrofitted	*11,538*	*14,265*	*16,764*	*19,058*
	Floors Retrofitted	*51,850*	*64,105*	*75,332*	*85,643*
	Windows Retrofitted	*65,677*	*81,199*	*95,421*	*108,481*
	Lofts Retrofitted	*27,477*	*33,971*	*39,921*	*45,385*
	Ventilation Retrofitted	*51,850*	*64,105*	*75,332*	*85,643*
	Thermal Bridging Reduction	*51,850*	*64,105*	*75,332*	*85,643*
Rural Off-Grid	Solid Walls Retrofitted	*17,617*	*21,768*	*25,569*	*29,080*
	Cavity Walls Retrofitted	*8,773*	*10,841*	*12,734*	*14,482*
	Floors Retrofitted	*27,201*	*33,612*	*39,481*	*44,903*
	Windows Retrofitted	*34,455*	*42,576*	*50,009*	*56,877*
	Lofts Retrofitted	*29,937*	*36,993*	*43,452*	*49,419*
	Ventilation Retrofitted	*27,201*	*33,612*	*39,481*	*44,903*
	Thermal Bridging Reduction	*27,201*	*33,612*	*39,481*	*44,903*

Table 72. Heat Metrics Summary, High GI, Low UT Scenario

		2010	2020	2030	2040	2050
Total Heat and Cooling Demand	TWh	96.13	91.60	89.07	86.26	83.37
Non-Electric Heat Demand	TWh	78.70	72.74	63.32	51.42	43.67
Total Fuel Consumption	TWh	99.93	91.11	83.66	77.39	72.33
Total Non-electric, Non-biomass Fuel Consumption	TWh	84.63	79.37	66.99	52.75	43.66
Biomass fuel consumption for heat	TWh	1.642	3.16	5.87	7.69	9.18
Renewable Heat Delivered	TWh	1.696	7.93	17.41	22.93	26.34

A1.3.5 High Government Intervention, High Uptake Scenario

Table 73. Heat Demands, High GI, High UT Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic *Space heating & DHW*	Urban	Existing	TWh	*25.69*	*22.35*	*17.91*	*15.25*	*13.68*
		New-build	TWh	*0.00*	*1.28*	*2.00*	*2.57*	*3.14*
		Urban Total	TWh	***25.69***	***23.63***	***19.91***	***17.82***	***16.82***
	Rural On-Grid	Existing	TWh	*6.81*	*5.84*	*4.53*	*3.79*	*3.37*
		New-build	TWh	*0.00*	*0.19*	*0.29*	*0.37*	*0.44*
		Rural On-Grid Total	TWh	***6.81***	***6.04***	***4.83***	***4.16***	***3.81***
	Rural Off-grid	Existing	TWh	*4.23*	*3.57*	*2.68*	*2.19*	*1.94*
		New-build	TWh	*0.00*	*0.16*	*0.23*	*0.28*	*0.33*
		Rural Off-Grid Total	TWh	***4.23***	***3.73***	***2.91***	***2.48***	***2.28***
Domestic Total			TWh	**36.73**	**33.40**	**27.65**	**24.46**	**22.91**
Non-domestic *Space heating & DHW*	Urban	Existing	TWh	*6.48*	*6.03*	*5.59*	*5.17*	*4.76*
		New-build	TWh	*0.00*	*0.51*	*0.81*	*0.98*	*1.16*
		Urban Total	TWh	***6.48***	***6.53***	***6.40***	***6.14***	***5.92***
	Rural On-Grid	Existing	TWh	*1.17*	*1.08*	*0.99*	*0.91*	*0.83*
		New-build	TWh	*0.00*	*0.06*	*0.09*	*0.11*	*0.14*
		Rural On-Grid Total	TWh	***1.17***	***1.14***	***1.09***	***1.02***	***0.97***
	Rural Off-grid	Existing	TWh	*0.11*	*0.10*	*0.10*	*0.09*	*0.08*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.02*	*0.03*
		Rural Off-Grid Total	TWh	***0.11***	***0.12***	***0.12***	***0.11***	***0.11***
Non-domestic Total			TWh	**7.75**	**7.78**	**7.60**	**7.28**	**7.00**
Industrial Total			TWh	**48.0**	**44.3**	**40.9**	**37.9**	**35.2**
	Catering & Cooking Demand		TWh	2.36	2.72	3.07	3.47	3.93
	Cooling Demand		TWh	1.27	1.41	1.59	1.86	2.20
	Total Heating and Cooling Demand for Scotland		TWh	**96.13**	**89.59**	**80.84**	**74.98**	**71.23**

Table 74. Total Energy Demand, High GI, High UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	TWh	*29.09*	*23.88*	*15.41*	*11.76*	*9.98*
		New-build	TWh	*0.00*	*1.24*	*1.36*	*1.49*	*1.68*
		Urban Total	TWh	***29.09***	***25.12***	***16.76***	***13.26***	***11.66***
	Rural On-Grid	Existing	TWh	*7.65*	*6.19*	*4.07*	*2.95*	*2.36*
		New-build	TWh	*0.00*	*0.20*	*0.18*	*0.28*	*0.36*
		Rural On-Grid Total	TWh	***7.65***	***6.39***	***4.24***	***3.23***	***2.72***
	Rural Off-grid	Existing	TWh	*4.54*	*3.53*	*2.24*	*1.62*	*1.31*
		New-build	TWh	*0.00*	*0.16*	*0.14*	*0.22*	*0.28*
		Rural Off-Grid Total	TWh	***4.54***	***3.69***	***2.37***	***1.84***	***1.59***
Domestic Total			TWh	**41.27**	**35.20**	**23.38**	**18.33**	**15.97**
Non-domestic	Urban	Existing	TWh	*9.47*	*7.84*	*6.95*	*6.31*	*5.74*
		New-build	TWh	*0.00*	*0.59*	*0.99*	*1.34*	*1.78*
		Urban Total	TWh	***9.47***	***8.44***	***7.95***	***7.65***	***7.51***
	Rural On-Grid	Existing	TWh	*1.03*	*0.86*	*0.76*	*0.69*	*0.62*
		New-build	TWh	*0.00*	*0.08*	*0.13*	*0.16*	*0.22*
		Rural On-Grid Total	TWh	***1.03***	***0.94***	***0.89***	***0.85***	***0.84***
	Rural Off-grid	Existing	TWh	*0.15*	*0.14*	*0.12*	*0.11*	*0.11*
		New-build	TWh	*0.00*	*0.01*	*0.02*	*0.03*	*0.04*
		Rural Off-Grid Total	TWh	***0.15***	***0.15***	***0.15***	***0.15***	***0.15***
Non-domestic Total			TWh	**10.65**	**9.52**	**8.98**	**8.64**	**8.51**
Industrial		Chemicals	TWh	*6.0*	*5.3*	*4.6*	*4.0*	*3.5*
		Metals and Minerals	TWh	*1.0*	*0.9*	*0.8*	*0.7*	*0.6*
		Refineries and Other Energy Industry	TWh	*18.5*	*18.0*	*17.6*	*17.2*	*16.7*
		Other	TWh	*22.5*	*20.1*	*17.9*	*16.0*	*14.3*
Industry Total			TWh	**48.01**	**44.28**	**40.92**	**37.91**	**35.19**
Total Energy Demand for Heating and Cooling in Scotland			TWh	**99.93**	**89.00**	**73.29**	**64.88**	**59.66**

Table 75. GHG Emissions Summary, High GI, High UT Scenario

Geography			Units	Year				
				2010	**2020**	**2030**	**2040**	**2050**
Domestic	Urban	Existing	$MtCO_2e$	*6.91*	*4.68*	*2.22*	*1.11*	*0.63*
		New-build	$MtCO_2e$	*0.00*	*0.22*	*0.17*	*0.11*	*0.07*
		Urban Total	$MtCO_2e$	***6.91***	***4.90***	***2.39***	***1.22***	***0.71***
	Rural On-Grid	Existing	$MtCO_2e$	*1.96*	*1.32*	*0.76*	*0.44*	*0.28*
		New-build	$MtCO_2e$	*0.00*	*0.03*	*0.01*	*0.01*	*0.01*
		Rural On-Grid Total	$MtCO_2e$	***1.96***	***1.35***	***0.77***	***0.45***	***0.29***
	Rural Off-grid	Existing	$MtCO_2e$	*1.55*	*0.89*	*0.42*	*0.22*	*0.13*
		New-build	$MtCO_2e$	*0.00*	*0.02*	*0.01*	*0.01*	*0.01*
		Rural Off-Grid Total	$MtCO_2e$	***1.55***	***0.91***	***0.43***	***0.22***	***0.13***
Domestic Total			$MtCO_2e$	**10.41**	**7.16**	**3.59**	**1.89**	**1.12**
Non-domestic	Urban	Existing	$MtCO_2e$	*2.30*	*1.44*	*0.81*	*0.49*	*0.33*
		New-build	$MtCO_2e$	*0.00*	*0.07*	*0.05*	*0.03*	*0.02*
		Urban Total	$MtCO_2e$	***2.30***	***1.51***	***0.86***	***0.51***	***0.35***
	Rural On-Grid	Existing	$MtCO_2e$	*0.26*	*0.15*	*0.09*	*0.06*	*0.04*
		New-build	$MtCO_2e$	*0.00*	*0.01*	*0.01*	*0.01*	*0.00*
		Rural On-Grid Total	$MtCO_2e$	***0.26***	***0.16***	***0.11***	***0.06***	***0.04***
	Rural Off-grid	Existing	$MtCO_2e$	*0.05*	*0.03*	*0.02*	*0.01*	*0.01*
		New-build	$MtCO_2e$	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
		Rural Off-Grid Total	$MtCO_2e$	***0.05***	***0.04***	***0.02***	***0.01***	***0.01***
Non-domestic Total			$MtCO_2e$	**2.61**	**1.72**	**0.98**	**0.59**	**0.40**
Industrial		Chemicals	$MtCO_2e$	*1.58*	*1.08*	*0.65*	*0.42*	*0.28*
		Metals and Minerals	$MtCO_2e$	*0.33*	*0.22*	*0.13*	*0.08*	*0.05*
		Refineries and Other Energy Industry	$MtCO_2e$	*5.38*	*4.21*	*2.67*	*1.84*	*1.23*
		Other	$MtCO_2e$	*6.31*	*4.84*	*3.61*	*2.68*	*1.97*
Industry Total			$MtCO_2e$	**13.60**	**10.35**	**7.07**	**5.02**	**3.52**
Total GHG Emissions for Heating and Cooling in Scotland			$MtCO_2e$	**26.62**	**19.22**	**11.63**	**7.50**	**5.05**

Table 76. Cost Summary: OPEX, High GI, High UT Scenario

Geography			Units	2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	*1,388*	*1,432*	*1,119*	*1,194*	*1,304*
		New-build	£m	*0*	*74*	*100*	*153*	*218*
		Urban Total	£m	***1,388***	***1,506***	***1,219***	***1,347***	***1,522***
	Rural On-Grid	Existing	£m	*366*	*376*	*301*	*317*	*349*
		New-build	£m	*0*	*9*	*14*	*18*	*21*
		Rural On-Grid Total	£m	***366***	***385***	***315***	***335***	***370***
	Rural Off-grid	Existing	£m	*292*	*315*	*234*	*216*	*221*
		New-build	£m	*0*	*10*	*12*	*14*	*17*
		Rural Off-Grid Total	£m	***292***	***325***	***246***	***230***	***238***
	Equipment Maintenance	Existing	£m	101	258	245	232	222
		New-build	£m	0	40	58	85	135
Domestic Total			£m	**2,147**	**2,514**	**2,084**	**2,229**	**2,487**
Non-domestic	Urban	Existing	£m	*368*	*408*	*390*	*426*	*446*
		New-build	£m	*-*	*35*	*67*	*111*	*177*
		Urban Total	£m	***368***	***443***	***457***	***537***	***623***
	Rural On-Grid	Existing	£m	*41*	*46*	*45*	*48*	*50*
		New-build	£m	*-*	*4*	*8*	*14*	*22*
		Rural On-Grid Total	£m	***41***	***50***	***53***	***62***	***72***
	Rural Off-grid	Existing	£m	*10*	*11*	*9*	*9*	*9*
		New-build	£m	*-*	*1*	*2*	*3*	*5*
		Rural Off-Grid Total	£m	***10***	***12***	***11***	***12***	***14***
	Equipment Maintenance	Existing	£m	***21***	***21***	***20***	***19***	***18***
		New-build	£m	***-***	***2***	***2***	***3***	***3***
Non-domestic Total			£m	**440**	**527**	**543**	**632**	**729**
Industry		CCS Costs	£m	*-*	*-*	*63*	*80*	*90*
		Fuel Purchase	£m	*1,981*	*2,553*	*2,511*	*2,752*	*3,018*
District Heating			£m	***5***	***65***	***193***	***350***	***552***
Scotland Total OPEX			£m	**4,573**	**5,659**	**5,394**	**6,043**	**6,876**

Table 77. Cost Summary: Average annual CAPEX, High GI, High UT Scenario

Geography			Units	Year				
				2010	2020	2030	2040	2050
Domestic	Urban	Existing	£m	-	*619*	*781*	*704*	*647*
		New-build	£m	-	*208*	*441*	*490*	*605*
		Urban Total	£m	**-**	***826***	***1222***	***1194***	***1252***
	Rural On-Grid	Existing	£m	-	*120*	*123*	*87*	*79*
		New-build	£m	-	*29*	*64*	*72*	*86*
		Rural On-Grid Total	£m	**-**	***149***	***187***	***159***	***165***
	Rural Off-grid	Existing	£m	-	*31*	*52*	*47*	*43*
		New-build	£m	-	*14*	*42*	*47*	*56*
		Rural Off-Grid Total	£m	**-**	***45***	***95***	***94***	***99***
		Cost of new-build offsets	£m	**-**	*4*	*14*	*4*	*0*
	Fabric retrofit & new-build		£m	**-**	*322*	*988*	*943*	*1063*
Domestic Total			£m	**-**	**1346**	**2506**	**2393**	**2578**
Non-domestic	Urban	Existing	£m	-	*35*	*29*	*26*	*6*
		New-build	£m	-	*6*	*8*	*9*	*9*
		Urban Total	£m	**-**	***41***	***37***	***35***	***15***
	Rural On-Grid	Existing	£m	-	*4*	*3*	*3*	*3*
		New-build	£m	-	*0*	*1*	*1*	*1*
		Rural On-Grid Total	£m	**-**	***4***	***4***	***4***	***4***
	Rural Off-grid	Existing	£m	-	*0*	*1*	*1*	*0*
		New-build	£m	-	*0*	*0*	*0*	*0*
		Rural Off-Grid Total	£m	-	***1***	***1***	***1***	***1***
		Cost of new-build offsets	£m	**-**	*1*	*4*	*0*	*0*
	Fabric retrofit & new-build		£m	**-**	*91*	*540*	*788*	*922*
Non-domestic Total			£m	**-**	**139**	**586**	**827**	**942**
District Heating			£m	**-**	*34*	*85*	*94*	*93*
Scotland Total CAPEX (average annual value for preceding decade)			£m	**-**	**1519**	**3178**	**3314**	**3614**

Table 78. Heat Supply technologies delivered, Domestic Sector, High GI, High UT Scenario

Technologies delivered: Domestic		Existing stock, units				New-build stock, units			
	Technology	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Urban	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	616485	0	0	0	55753	0	0	0
	Resistive heating	0	0	46538	45138	0	0	0	0
	Oil-fired boiler	0	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	43077	116329	108060	104810	66373	79185	96677	383493
	Stirling engine µCHP	66786	0	0	0	17699	0	0	0
	Fuel-cell µCHP	66786	0	0	0	17699	0	0	0
	Air-source heat pump	133572	450888	418838	406241	17699	174868	226611	0
	Ground-source heat pump	34122	129405	120206	116591	8850	62453	80933	106526
	District heating	52864	171838	159624	154823	20150	0	0	24780
Rural On-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	130084	95671	0	0	9274	0	0	0
	Resistive heating	0	10630	10161	9830	0	0	0	0
	Oil-fired boiler	0	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	2537	6888	6584	6370	10047	11196	41242	56393
	Stirling engine µCHP	14092	0	0	0	2679	0	0	0
	Fuel-cell µCHP	14092	0	0	0	2679	0	0	0
	Air-source heat pump	32521	95671	91445	88467	2679	25564	0	0
	Ground-source heat pump	1613	4613	4410	4266	1340	9130	11456	15665
	District heating	0	0	0	0	0	0	0	0
Rural Off-Grid	Gas boiler (old)	0	0	0	0	0	0	0	0
	Gas boiler (new)	0	0	0	0	0	0	0	0
	Resistive heating	0	5548	5302	5153	0	0	0	0
	Oil-fired boiler	2844	0	0	0	0	0	0	0
	Solid-fuel boiler	0	0	0	0	0	0	0	0
	Biomass Boiler	1774	4794	4581	4452	6700	7306	26781	36259
	Stirling engine µCHP	0	0	0	0	0	0	0	0
	Fuel-cell µCHP	0	0	0	0	0	0	0	0
	Air-source heat pump	22748	49935	47718	46373	1787	16864	0	0
	Ground-source heat pump	1228	2796	2672	2597	893	6023	7439	10072
	District heating	0	0	0	0	0	0	0	0

Table 79. Heat Supply Technologies Delivered, Non-domestic Sector, High GI, High UT Scenario

Technologies delivered: Non-domestic		Existing stock, TWh of supply				New-build stock, TWh of new supply			
Geography	**Technology**	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Urban	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	2.58	0.00	0.00	0.00	0.15	0.00	0.00	0.00
	Resistive heating	0.00	0.00	0.17	0.04	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.32	1.29	1.14	0.26	0.07	0.21	0.25	0.29
	Stirling engine µCHP	0.11	0.00	0.00	0.00	0.04	0.00	0.00	0.00
	Fuel-cell µCHP	0.56	0.00	0.00	0.00	0.04	0.00	0.00	0.00
	Air-source heat pump	0.28	0.38	0.34	0.08	0.13	0.24	0.27	0.32
	Ground-source heat pump	0.03	0.06	0.05	0.01	0.02	0.04	0.04	0.05
	District heating	0.42	0.72	0.63	0.15	0.05	0.11	0.06	0.07
Rural On-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.27	0.00	0.00	0.00	0.00	0.03	0.00	0.00
	Resistive heating	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.05	0.19	0.17	0.16	0.00	0.03	0.03	0.04
	Stirling engine µCHP	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.03	0.04	0.04	0.03	0.00	0.01	0.04	0.04
	Ground-source heat pump	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	District heating	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Rural Off-Grid	Gas boiler (old)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gas boiler (new)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Resistive heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil-fired boiler	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Solid-fuel boiler	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass Boiler	0.01	0.03	0.03	0.03	0.00	0.01	0.01	0.01
	Stirling engine µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fuel-cell µCHP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Air-source heat pump	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	Ground-source heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	District heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 80. Domestic retrofit measures delivered, High GI, High UT Scenario

		2020	2030	2040	2050
Urban	Solid Walls Retrofitted	*88,815*	*255,818*	*330,267*	*367,590*
	Cavity Walls Retrofitted	*124,999*	*360,040*	*464,820*	*517,349*
	Floors Retrofitted	*245,722*	*707,766*	*913,741*	*1,017,002*
	Windows Retrofitted	*311,248*	*896,504*	*1,157,405*	*1,288,203*
	Lofts Retrofitted	*188,470*	*542,859*	*700,843*	*780,044*
	Ventilation Retrofitted	*245,722*	*707,766*	*913,741*	*1,017,002*
	Thermal Bridging Reduction	*245,722*	*707,766*	*913,741*	*1,017,002*
Rural On-Grid	Solid Walls Retrofitted	*10,855*	*31,380*	*40,738*	*45,266*
	Cavity Walls Retrofitted	*11,538*	*33,355*	*43,302*	*48,115*
	Floors Retrofitted	*51,850*	*149,888*	*194,588*	*216,215*
	Windows Retrofitted	*65,677*	*189,858*	*246,478*	*273,872*
	Lofts Retrofitted	*27,477*	*79,431*	*103,119*	*114,580*
	Ventilation Retrofitted	*51,850*	*149,888*	*194,588*	*216,215*
	Thermal Bridging Reduction	*51,850*	*149,888*	*194,588*	*216,215*
Rural Off-Grid	Solid Walls Retrofitted	*17,617*	*50,832*	*66,193*	*73,760*
	Cavity Walls Retrofitted	*8,773*	*25,314*	*32,964*	*36,733*
	Floors Retrofitted	*27,201*	*78,488*	*102,208*	*113,892*
	Windows Retrofitted	*34,455*	*99,419*	*129,463*	*144,263*
	Lofts Retrofitted	*29,937*	*86,382*	*112,487*	*125,347*
	Ventilation Retrofitted	*27,201*	*78,488*	*102,208*	*113,892*
	Thermal Bridging Reduction	*27,201*	*78,488*	*102,208*	*113,892*

Table 81. Heat Metrics Summary, High GI, High UT Scenario

		2010	2020	2030	2040	2050
Total Heat and Cooling Demand	TWh	96.13	89.59	80.84	74.98	71.23
Non-Electric Heat Demand	TWh	78.70	68.22	49.13	38.46	31.81
Total Fuel Consumption	TWh	99.93	89.04	73.35	64.94	59.66
Total Non-electric, Non-biomass Fuel Consumption	TWh	84.63	74.64	49.49	36.48	28.87
Biomass fuel consumption for heat	TWh	1.642	5.00	11.10	14.65	17.20
Renewable Heat Delivered	TWh	1.696	9.58	23.87	30.14	34.11

Appendix B

References

B1 Explanatory note

The list below sets out documentary and data sources used for the Scottish Heat Pathway Scenarios Model (HPSM). Where databases were used, the date when the database was received or interrogated is indicated.

B2 Key References

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Appendix C

Notes on Stakeholder Engagement

C1.1 Stakeholder Workshop – 22 October, 9am to 11.30am

Attendees

Sue Roaf	Herriot-Watt University

Question / Comment	Response
METHOD AND MODEL	**METHOD AND MODEL**
S. Roaf – has ex-student – George – completed a solar water study of Dundee to provide hot water heating. Robust study.	Arup to follow-up.
S. Roaf – example of how performance can go wrong, eg building regulations on non-domestic and you pass if buildings has air conditioning and penalised if you have natural ventilation, HVAC body has influenced this? Should window manufacturers be involved too? Or you could say that we could have no more air conditioning in Scotland via regulation.	
S. Roaf – can provide real data on costs of energy usage per technology to act as a calibration check, or as a narrative. Difference between kW peak. Dundee has agreed city-wide prices, so could be useful. S. Roaf can provide Scotland-wide data on a quick turnaround – and available to be published.	SLM noted that this still can't be applied across the country.
S. Roaf – no mention of fuel poverty – how does it figure in model.	SLM – partly comes of out of costs of scenarios. How the costs are being scribed to population is not being undertaken by this model.
S. Roaf – what you are basing future energy costs on.	TH – on DECC's future projections which are published, Sept 2013. Does not include strike prices for nuclear, which won't be reflected in DECC's published projections until April 2014.
SCENARIOS	
S. Roaf - Public acceptance – noted that this is also private action. It's not just 'understanding' or 'uptake' of technologies by the public.	
S. Roaf – is it a relationship between income and cost of technology? SLM, not it's not that simple, otherwise wouldn't need regulation of energy companies.	
SLM – we aren't dealing with unused useful heat? Might come up in the questions from stakeholders.	TH – straightforward to build 'secondary' heat into the model. Even if data are not yet available. Potential to have district heating as a separate model which includes the technologies eg biomass, waste heat etc

C1.2 2020 Groups Stakeholder Workshop – 22 October, 2pm to 4.30pm

Attendees

Cameron Maxwell	Forestry Commission
Stephanie Clark	Scottish Renewables
Duncan MacKinnon	Tilhill Forestry Ltd
Charles Smith	Brodies Solicitors
Fiona Ross	Pinsent Masons LLP
Viv Cockburn	Scottish Futures Trust
Chris Ridgway	Head of Commercial Development, Forth Energy
Neil Holland	Sales & Marketing Director, Brites
David Cameron	Head of Scottish Policy, Corporate Policy and Regulation, EDF Energy
Rona Gold	Policy Manager - Waste, Carbon and Climate Change, COSLA
Stevie Adams	Green Deal Operations Manager, SSE
Stuart Reid	Head of Marketing & Business Development, HWEnergy Ltd
Ann McKenzie	Fuel Poverty Policy, Scottish Government
Rob Shuttleworth	CEO UK LPG
Colin Clarke	Energy Manager, Engineering & Environment, NHS National Services Scotland
John Forbes	The Energy Saving Trust

Question / Comment	**Response**
METHOD AND MODEL	
Biomass – availability in Scotland and capping it based on what's available in Scotland? Further question – understanding the maximum cap that is key to the model.	SC – it would be a useful answer to get information on.
Fuels prices – does the model allow gas price changes to be modelled?	SC – yes, it is one of the exogenous external drives.
Energy from waste – is it contributing to the model?	Yes.
Does model allow for secondary heat ie re-use of industrial waste heat?	SC – main answer is yes. Likely to have separate district heating module that would allow delivery systems including waste heat, CHP etc
Gas pipe network – as part of a network for green gas, important point for getting green gas injection into people's homes.	
How will you take account of electricity as a base for heat? If a house has both gas and electricity, how will you determine where the line is drawn for supply? Also how will you model how efficiently how the fuels are used?	

Question / Comment	Response
Eg between a new and an old boiler? It is being modelled by increasing efficiencies of technologies over time.	
Carbon content of electricity?	Grid decarbonisation data from DECC. Plus changing electrical demand. Not looking at targets, it's looking at projection therefore doesn't provide answers on meeting targets.
Fuel cells – increasing in Japan. Therefore model should be able to provide ability to take into account decentralised energy as well as grid energy.	
Will model be used to develop targets?	SG - Heat vision to 2050 provides targets. The scenarios from this work will then be considered by SG what their next steps are. SG can't say what targets they'll have at this stage, they need to consult on the HGPS first before considering any targets.
Is it part of the scope to model financial incentives?	Yes, the model incorporates cost information and marginal cost information. It will be possible to understand what the cost of heat mixes are as well as model subsidies etc on the investments.
Noted that it was important that there are some subsidies that could be provided by private investment instead. Is the model concerned with capital as well as revenue?	SC yes, it is.
DATA SOURCES	
Biomass – have 25 year focus for soft wood. It gives availability out to 2035 and is a forecast based on modelling based on what is in the ground at the moment.	Forestry Commission data, previously discussed with Hugh Muschamp.
Do we have any results yet?	SC - Not yet, model is built
Are there any other constraints that are in the model that we should be aware of?	Waste heat, secondary heat, and low grade heat – what data are available for that? Also constraints on different types of technologies in each property.
Could the model have properties having 100% heat from heat pumps?	Yes it could, but only those for which the property is suitable.
Can the model look at new opportunities eg algae production for biofuels/biogas?	SC – potentially, although whether it would be a major contributor at a national scale would need to be considered.
Does it take account of geothermal?	SC – yes.
Fear that the model will be very complicated. More confident up to 2030 but after this point there will be more disruptive technologies.	
We'll have no gas network and no fossil fuel network by 2050.	SC – Is there data that can support this?
What is the desired outcome of the model?	A range of scenarios that have credibility across a range of stakeholder representatives.
What they would like to see is cost benefit analysis coming out of the model eg off grid	

Question / Comment	Response
areas getting district heating. So up to 2030 they would like to see scenarios on clear and specific policy actions that would allow that to happen.	
Unconventional gas – syn gas, hydrogen and biomethane gas. Gas networks being incentivised to connect to conventional gas networks. TSOs identified as a possible source. Southern Ireland UCC Cork have lots of work on biogas – can provide contacts.	SC – There are no data that we are happy with as yet.
Heating and Hot Water Industry Council – have been working on alternative pathways. They have DECC workshop w/c 28 Oct. They represent industries for domestic heating companies. There is ICOM who have the industrial equivalent. Contacts to be provided to SG.	
Heat pumps – a more pressing issue might be what the distribution networks look like rather than on actual supply that is the constraint.	
Limitation – grid connection, air quality, carbon neutrality of biomass, international trade of wood pellets are also constraints. What is biomass carbon neutral? Is it now, is in in 25 years' time?	
Market at the moment for wood pellets and forecast for 25 years. Northern Ireland is a good source of biomass. There are a number of programmes that have been run there that might be useful. 2005 model and also what the price point is for switching from oil. Similar climate to Scotland – housing executive is body responsible for all social housing. Have switched housing from coal / oil to gas / biomass. Good housing stock survey. Information on price elasticity – when do they switch across – what is the price point? UREG – northern Ireland utility regulator.	
Constraints on biomass and its importation – might be scale of Scottish Ports and their availability/capability to import. Could impact on it being low carbon.	
On high grade heat for industrial uses, are we separating fuels for that? Are we constraining the other technologies in these areas?	Yes.
Different business models will they make uptake higher. Whether different business models like ESCos would make uptake higher?	SLM sees that fitting under public action/acceptance.
How much does the model take account of new business model approach? Eg If you look at new build, standards now to 2015, but there were companies in the sector who were lobbying for this. How much SG subsidy needs to go in?	Model separates cost to government and cost to consumer.

Question / Comment	**Response**
Functionality of the model – can it be used by industry to play around with figures?	Physically it could be but it's up to SG to determine whether it does.
Where are we at on the call for evidence for cost of district heating – has it been completed?	SLM the Heat Network Partnership is looking at it specifically however unlikely to be completed in time to be fed back to this model. Likely that the model will have to be reviewed in the short-term to enrich it with this type of data outputs.
ASSUMPTIONS ON UPTAKE OPPORTUNITIES and BARRIERS & SCENARIOS	
Costs – do these include wayleaves and permitted development situations for district heating?	At the moment it's £/kWh. Is the model going to evolve to include all these? Uptake rates may be more of a constraining factor that costs. The model boils it down to a relatively simple number but it's the evidence of how long it takes district heating to get built that is needed to refine model.
Transparency, longevity, certainty.	
RHI – EMR – works for smaller solutions, biomass technologies rather than larger technologies – this is to do with whether you can book in advance; do you know what your incentive's going to be. Same story as with EMR.	
Incentivisation of district heating – has been proposed by Northern Ireland.	
High interventions – where government are picking a particular technology or any long-term intervention would be a high government intervention – which is also what industry needs. High intervention does necessarily relate to higher cost.	
Regulation – you can regulate in a non-technology-specific rate.	
Pilot programmes/schemes – high government intervention and high public acceptance, which is different than providing a market and letting the market decide.	
Infrastructure development – should the government be more involved? Eg gas network only exists because the government built it. Should this happen again? Government could have a direct role to play in DH development and then hand over to private sector once de-risked. . Lower level in terms of building regulation changes – big driver for new-build. But Northern Ireland is private, although it's regulated but pipes weren't put in by government.	
New build driven by higher efficiency boiler. So join up thinking with scrappage schemes.	
High acceptance of natural gas through public sector implementing it in housing stock and public buildings. It built public sector.	

Question / Comment	Response
Interventions and technologies are also determined by geography.	
2007/8 BRE reported on all domestic boilers had 12 year lifetime which meant that in 2020 there would be a chance to change all boilers in the UK ie change 1/12 of all boilers every year. Could be a useful data source.	
Comparison between FiT and RHI has 'worked'. FiT compared solar PV with domestic heating. PV took off on the back of FiT as an individual fitting the system now as you would have been fitting it in the original scheme. Compared to the RHI however, at the same time as the FiT, the RHI is coming along three years later than expected but that has dimmed market, which now needs reinvigorating. The solar panel has only risk that you don't generate enough revenue to cover costs. Whereas RHI has the risk that the system isn't sized properly, which payment doesn't necessarily cover? Comparison to leaded and unleaded petrol. Low acceptance was initially there but then fear didn't transpire and it changed quickly. But it was high government intervention that implemented it in low acceptance climate. However, it was successful.	
Change could be to change to buying 'heat' and not 'fuel' for your boiler. Risk could be taken by ESCo and not customer. For example like energy companies who supply gas but don't actually physically supply it. Potential to do that for heat. But need significantly sized DH network to do that.	
Industrial side – is there any opportunity to drill down into the specific types of industries that are large heat generators or organic biowaste heat generators? Can potentially get 'easy wins' but currently there isn't an incentive push for this. Is there a benefit in mapping that out?	
Public acceptance – at the point where a customer will switch over will be driven by the bottom line. Need three to four year payback before it will get uptake. Needs to have greater than 12% IRR on a term longer than this. But this could be eased by ESCo model but does depend who is financing ESCo. Overcome risk of switching to heat through attractive business case – high subsidy or high counterfactual (e.g. skyrocketing fossil fuel prices).	

C1.3 Individual Solutions Stakeholder Workshop – 23 October, 9am to 11.30am

Attendees

David Pearson	Star Refrigeration
Joe Fergusson	Renewables Consultant, Energy Agency
Graham Esson	Perth & Kinross Council
Dr David Hawkey	Research Fellow, Heat and the City, The University of Edinburgh
Andrew Faulk	Consumer Futures
Dominic Sims	City Energy Manager, Community Strategy & Market Development, Scottish Power
Brian Mc Robert	ECO Development Manager, npower energy services
Anthony Kyriakides	Manager, Scottish Renewables, Energy Saving Trust
Paul Blacklock	Head of Strategy and Corporate Affairs, Calor Gas Ltd
Neville Martin	Manager, Shetland Heat Energy and Power Ltd
Sandy Wito	Head of Business Development, Seven Cities Development Team, SSE
Daniel Borisewitz	Senior Consultant, SLR Consulting LTD
Elaine McCall	SEA Technical Support Officer, SG
Lewis Hurley	SEA Specialist, SG

Question / Comment	Response
METHOD AND MODEL	
Is urban off-grid included in model?	Yes, through the technology that is assumed for properties.
Can model be applied to local context?	SLM – the model has been designed to support a nation-wide policy and therefore is not built to determine the best technologies for local authorities/typologies.
Question over whether the model can drill down to a bit more detail, e.g. with better heat mapping.	Model is at Scottish National level, more detail provides clarity and resolution to assumptions but not appropriate for micro-scale analysis.
DATA	
What happens to model once it's given to SG?	SLM - Arup has been asked to develop scenarios that investigate how we'll meet our targets. Scenarios will include costs, used as a means of identifying key issues with achieving the targets, and use to discuss with key stakeholders. The model will be used to determine how targets to 2050 can be met and it will be shared with stakeholders through the consultation process.
EPC data and SHCS what is the source of that?	SLM, SHCS is a sample of 3,000 houses of the stock in Scotland. EPC data is collected on sale/rent of housing.
When you are happing heat demand – what	SC Heat mapping is normally done by energy but it also picks up what type of energy is there

Question / Comment	Response
temperature are you assuming?	and this normally tells you what the temperature is. Heat mapping that we have used has been primarily on the commercial side. We have used mapping of heat demand but not temperature demand. Heat mapping is most useful for determining district heating potential.
Geothermal – what are you talking about?	Deep geothermal.
Waste heat from power stations, or rivers or waste water treatment centres - are these in the model?	Yes, they can be.
How do you determine competing technologies within the model eg if CHP and district heating are available in the location?	MAC is main driver for each of the technologies within the model. But model can be overridden to allow the users to influence technology.
How are significant national developments included in the model?	Model has growth and demolition rates. But it's numbers, not geographic. SLM this type of heat is residual and is considered. The heat mapping work will take this forward and can be used to update the model going forward.
Does the model cover socio-economic factors?	Costs that we have for the model are costs for the economy. The ability to pay or impact of fuel poverty is not built into the model. SLM the current situation and the ability to pay are taken into account by comparing the model demand to the actual demand to what is being used now as a calibration check. Data may be available on where the tipping points are on social housing for affording heating.
Constraints – in practice we're finding that on heat networks the usage evidence is not as predicted. For example demand is 50% less than anticipated. DH networks see consistently less demand than forecast based on SAP calculations. Price of heat adds serious challenges. It also depends on the way that the heat is being charged eg if the heat is paid for within rent then it is used all the time. So factoring real life data.	
Availability of electricity grid will also be a constraint to usage, particularly when domestic RHI comes on board. The availability of grid will need to be improved.	SC – the model is just a heat model so one of the outputs is electricity demand. It will then be fed into a different electricity model. The constraint will particularly apply to rural area.
Some DNOs are looking at second generation storage heaters – this could be factored in? Daily electricity usage is 'spiky' and if you don't use heat pumps during the spike periods then it levels out the electricity use. These results tell you that the production capacity is there. If you flatline consumption at the peak electricity demand rate and then use smart technologies to 'fill in' the trough on the daily/seasonal basis – peak never gets higher. Also heat pumps able to enable, e.g. wind, that is being shed nowadays. Serious role to play for smart systems. Storage and smart meters /	

Question / Comment	Response
smart controls / despatch.	
Data available on the grid reinforcements and where electricity bases are being used.	
Gas absorption heat pumps – are they included in model?	
DECC and EST has completed field trials	
ONS data on the amount of gas energy used to heat homes has decreased over last 10 years by 20%. Due to improved efficiency but also due to the cost of gas increasing.	
Climate change predictions in model and comments on the met office temperature data – is it most appropriate for calculating heat demand? It isn’t clear that due to behaviour in colder months, whether heat demand does correlate directly with temperature.	
If climate change effects are only in warming, need to make sure that it doesn’t skew the data but not including extreme winter events.	The model has seasonal projections for temperatures and winter temperatures are set to get colder over time.
DNOs may be able to share aggregate data on consumption of gas and electricity. General acknowledgement that the data are patchy. Local authorities may have some specific data that could be helpful.	
Emerging technologies and how they are included in the model.	Need some evidence on how costs evolve over time.
ASSUMPTIONS and DRIVERS and SCENARIOS	
RHI is a game-changer for economics is uncertainty after 2015 is that it doesn’t incentivise other forms of renewable heat after this date. Carbon targets may be a more incentivising than just renewables commitment.	
Industrial sector, not enough time for CRC hasn’t been around long enough to have impact.	
Scenarios should focus on: low government intervention, increasing education.	
Industry appears risk averse to new technology, procurement rules are a barrier.	
Low government intervention would be level of education for all industry, local authority and domestic.	
New finance models could be game changers.	
Heating in domestic scenario – people aren’t thinking about it all the time. In private sector only change when heating breaks. They aren’t considering other options. Vast majority of people change their system when it breaks, often in winter, think quickly and just go for next saving, not alternatives. There isn’t a	

Question / Comment	Response
chance to influence their changes. Their choices are influenced by bad stories that they've heard, equally they are influenced for good stories.	
Potentially influence for private sector landlords who aren't incentivised at the moment. Similar to developers, they aren't required to connect to DH systems. Through planning in London this is mandatory – potential opportunity for that in Scotland.	
Interventions – transparency, longevity and certainty on what government is doing. Examples of where low government intervention schemes have had short-term impacts eg boiler scrappage scheme but it was short-lived and low budget but encourages early adopters.	
For solar PV FiT higher intervention has been successful in bringing on technology.	
Unconventional gas, cost projections have been used but don't know what the costs are going to be in the future. Price of energy is external driver and influences all technologies eg fracking etc.	
A key point is the influence of energy prices on behaviour.	
For domestic energy, the technology replacement timeline may not be as important a factor in replacement compared to renovation timescales.	
Domestic scenario – there is a fear of adopting new technologies. If you were installing a whole house technology eg biomass, it is a disruptive renovation project. So it's about overcoming the hurdle rate. EST has Green Homes network, it's still not getting through to domestic owners.	
On commercial scale, what impact has the uncertainty over the RHI and CfDs incentive schemes has had. The on-going consultations have built in uncertainty has slowed the market down. This in turn impacts the consumer as they have also had the uncertainty, this particularly true around biomass CHP. Commercial scale; impact of uncertainty around the RHI and CfDs has had impact, e.g. on biomass CHP, consultations, when is it going to get built, what is it applicable for? Huge implications on development across the board. Prevents finance. Impact of SG policy to not support large biomass alone; need to be CHP-ready, limited to what you can do on an industrial scale.	
Long-term feedstock contracts 8-10 year but	

Question / Comment	Response
what's on offer is 2-5 years which is having big impact on development. Until we see changes in terms of market conditions there need to be large incentives / government intervention. How much coal is being used for electricity generation? Until there is large incentives and strong policy there will be no change. Overcoming consumer concern and government intervention.	
When looking to develop DH network you need anchor loads, the ownership of public buildings and the requirements to connect to a DH network. Local authority buildings need to lead by example. Public buildings need to be exemplar – they need to lead by examples and influence consumers.	
Government ambitions have tried to be forced on consumers. However, consumers would rather spend their money on other things. Ambitions forced on consumers are not going to be realised. Instead reduce slope of ambition and make more incremental changes. Climate change is not a driver – cost for consumers is major influence. Heat pumps are only being used by people who are switching from oil and LPG.	
On energy security – islands tend to be more aware of it and are influenced by it. Similarly biomass users also are concerned about supply.	
On energy security – can look at where disasters/disruption has occurred abroad and how that has influenced energy supplies going forward. For example Fukushima disaster – have people changed their heating systems in their house.	
Green Deal financing is being picked up solicitors as being impairment rather than a benefit, as it adds to the electricity bill. Change needs to be made to attitudes.	

C1.4 District Heating Stakeholder Workshop – 23 October, 2pm to 4.30pm

Attendees

Brian Richardson	Greeningthemarket Ltd
Amy Stewart	Forestry Commission
Ali Rimell	Brodies Solicitors
Paul Moseley	Scottish Futures Trust
Janette Webb	The University of Edinburgh
Des McGinnes	The Buccleuch Estates Ltd
Mike Thomas	Head of Projects Forth Energy
Neil Kitching	Senior low carbon policy, Scottish Enterprise
Sarah Beattie-Smith	Policy and Parliamentary Officer , Citizens Advice Bureau
Robert MacGregor	Principal Engineer, Building Engineering, AECOM
Allan Crooks	Sector Specialist - Energy | Resource Efficient Scotland
Rebecca Carr	SG
Ian Conroy	SEPA
Janice Lyon	
Howard Roche	Vital Energi
John Sheridan	2020 Built Environment Group
Sam Gardner	WWF Scotland
David Stewart	SFHA
Rona Gold	COSLA
Ian Manders	CHPA
David Forbes	SSE
Colin Thomson	Scotia Gas Networks
Ken Brady	Programme Manager, District Heating, Energy Saving Trust
Andy Kerr	ECCI
Robert Sansom	Imperial College representing UKERC

Question / Comment	Response
METHOD AND MODEL	
Where does district heating sit within model – does DH have to pay for its own installation? How are we costing it? How is it included in the model?	SC – within the model, it's complicated. There is a module that deals with the inputs that make up the supply options for each of the sectors. On the costs, the costs are lifetime costs including infrastructure installation costs. SC notes that it's not a geographic model
What costs are we taking into account eg gas infrastructure, grid infrastructure etc?	SC – we are using published lifetime costs for each of the technologies. Not all costs will be included. Comment - Important that

Question / Comment	Response
	infrastructure costs are included
Brian Richardson – difficulty on meeting carbon targets (reducing to 2 tonne/yrs/person). They have tried modelling same thing but got stuck at 2030 and couldn't get to 2050, because we don't know it will look like.	SC – confirmed that we rejected backcasting model for this exercise, because forecasting doesn't predetermine the outcomes at this date. Andy Kerr – noting that this is a tool; it will not give the answer.
Sam Gardner WWF – want to know how model output results compare against Climate Change Act targets?	
Commercially available data set GreenAware – from Experian. It includes behaviour on a house-by-house basis. Previously available free to a similar project. Brian Richardson – considers EPC data are not granular.	SC – better to have country-scale data than detailed localised data.
Have we done a separate analysis of waste heat?	SC – no we haven't done any analysis, just collating data. Data are difficult to obtain.
EPC data are barely accurate down to 100 households.	
Ian – UK government obliges UK suppliers to give data on their suppliers – which can give a proxy for gas and electric data. National Energy Efficiency Data	SG doesn't yet have access to this, they have access to HEED but not NEED.
In terms of Non-Domestic heat – have they looked at CRC? All registered companies have to provide data on an annual database. 50,000 companies.	SC – not a data source that we've looked at and it would have to be in a format that can be used by us in the model.
DATA and MODEL	
Met office data for installation to look at the output from solar technologies. Data on technologies and efficiencies and growth in these to 2050.	
Change in temperature has been accounted for.	SC – wind speed has not been included.
Clearer goal for specific policy proposals needed at the end of it. Risk that we miss the legislative requirements coming down from EU, Scotland, Westminster. 11% decarbonisation of heat doesn't appear to be very high. Targets need to be set by future projections not current goals.	
Lifetime costs vary between technologies. This affects whether it gets implemented or not.	
Waste heat has to be a primary aspect from heat scenarios, should be forethought not an afterthought.	
Affordable is the main thing for the consumers.	
Data sources: EST report on low grade geothermal in the Central Belt, latent heat /	

Question / Comment	Response
background heat, SEPA data on sewage treatment sources and rivers, Industrial producers / distilleries. All gas that goes in ends up as waste heat. Gas networks report by Redpoint. Delta E scenarios on domestic gas usage.	
How the model deals with economics of current government policy?	
Forth Energy has some data available on capacity of ports to deliver biomass.	
Scottish Enterprise, waste water data as a heat source.	
Heat mapping – Forth Energy did have heat mapping data for Edinburgh and Grangemouth that could be available. Heat demand study: power in Edinburgh.	
Which levels of RHI are assumed for technologies currently under consultation?	
More data from CRC, NEED etc. Great deal of work done in West Midlands on heat. Excellent methodologies on data collection. Which sectors had to ramp up the most to reach the target.	
Be consistent with level of data that is used ie shouldn't be too bothered about detailed data. Domestic has quite a long lifecycle, non-domestic quite a different story, as for industrial. Be wary of missing costs and benefits when doing the analysis. Include the complete supply chain from supply to consumption.	
Take account of innovation for existing / non-existing technology. Take account of innovation as far as possible. TINA report issued recently. Be sure of technology suitability – a lot of stock will not work today with heat pumps, i.e. particularly storage. To get heat pump to work properly need to get 100s litres water storage. So not suitable for all housing stock.	
Be wary about treating heat on its own and not electricity. Include all features associated with local areas for heat storage – aquifers etc. Don't forget cooling.	Non-domestic cooling is in there as a thermal load.
All heat sources should be taken into account – so waste heat as well as primary heat.	
CHP DNOs want more intermittent generation in certain areas – which has been a problem for some clients.	
Unclear of relationship between model or policy? Particularly in relation to planning law and how that could impact uptake of	

Question / Comment	Response
CHP. Similarly with storage, it could that impact the uptake of CHP. Heat storage doesn't physically fit in model yet – may need to be addressed.	
If we said in 2015, the government wants to build X energy storage units and in 2030 wants Y energy storage units linked to district heating could we add this into the model?	
The extent to which the model will be interactive. Will the SG be able to edit in future?	
Cost around DH. Questions about fuel poverty – not entirely an issue of economics but still of political importance.	
Macro-economics of fuel import. How has becoming self-sufficient being incentivised?	
ASSUMPTIONS – UPTAKE RATES	
Scenarios – not just government intervention also regulators, DNOs and not just government. Strict targets like banning gas by 2050. Need geographical zoning eg in this part of the city will have no more gas or certain areas should be on district heating.	
Undermined by low gas cost, fracking, technology backlash, less successful air source heat pumps that expected so unexpected items such as war, cut off of Russian gas supply could dramatically alter the model.	
Domestic quick wins such as improved controls etc make sure that we're not missing that area, although difficult to characterise. Make sure that the transition is optimised and that we're not just getting the end target.	
Stimulants – scope for longer time incentives, RHI which has been good although no vision beyond 2015. Low carbon incentive rather than heat incentive would be good. Statement on government on connected stock.	
Making pipes in the ground compulsory in the ground for any new development. Any building that is being refurbished needs to have space for pipes etc and be network ready.	
Presumption to connect – this could be a stimulant. Clarity from SEPA and planning agencies on what should be implemented. As seen in other parts of the UK. Heat emissions and carbon footprint needs to be tightened up in planning.	

Question / Comment	Response
Scorecard for buildings should be provided. How they're assessed eg demand, reliance on foreign fuel, potential for further decarbonisation.	
Inhibitors, no presumption to connect. Network costs are felt to be high in the UK. Government should be taking initiative and putting the pipes in the ground and setting targets for district heating.	
High government intervention is capital support for schemes and then rent eg why can governments pay for roads but not pipes to put under them?	
Availability model for networks is high government intervention? Private sector developer builds the infrastructure and the state pays them for access to it. Scorecard of schemes. Try to move forward from the technology being agnostic.	
High government intervention is regulation. In that if you provide incentives or for free you still may not get high uptake rates, evidence for this.	
Decarbonising heat vs. cutting carbon emissions from your heat sector. Or you could deregulate or remove existing areas eg such as from conservation areas.	
Discussion looking at electricity supplies. For renewable electricity you could expect suppliers to provide a mix of technologies rather than a single technologies. Plus information on biogas in the network and how you could get to lower or zero carbon gas in the network and use existing network. Could you get suppliers to inject biogas by regulating or incentivising? Let's just reduce internal temperatures.	
Availability model – private sector builds it, government pays a fee to use it. Depends on when you look at capital or revenue support.	
When looking at large scale models you almost have to have regulation to get it installed.	
Gas network, owners are kicking back against biogas. But if the remit of their investment options included heat networks (ie digging holes in the ground) they might be less resistant.	