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Suitability of Buildings in Northern Ireland for Retrofitting Heat Pumps.

A Policy Tool for the Department for the Economy (DfE) (NI).

9th December 2022

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Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
4	December 2022	Final Issue	SH	Simon Hartley	Regional Director
3	October 2022	Final Issue	SH	Simon Hartley	Regional Director
2	September 2022	Comments Received	SH	Simon Hartley	Regional Director
1	July 2022	Updated Issue	SH	Simon Hartley	Regional Director
-	July 2022	Initial Issue	SH	Simon Hartley	Regional Director

Distribution List

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1. Introduction

AECOM has been contracted by the Department for the Economy (DfE) 'the Department' to research the suitability of buildings in Northern Ireland (NI) for the installation of heat pumps to better inform policy decisions in respect of low carbon heating.

1.1 Remit and Scope

This study, which comprises the review of literature and data sources, seeks to enable the Department to make informed decisions on policy matters by the development of the following tools:

- A bespoke tool to support the delivery of the Department's energy strategy objective of decarbonising heat, by providing an indicative assessment of whether a heat pump is a 'suitable' technology for a particular building type and whether each building type is likely to be 'heat pump ready'. This tool also outlines the likely need for any additional energy efficiency measures and evaluates the impacts of such measures.
- A self-assessment checklist/pro-forma that homeowners, small businesses, and public sector asset owners can use to easily determine if their building is potentially suitable for a heat pump.

The research assignment brief from the Department was as follows:

This study required all relevant aspects of retrofit heat pump installations to be considered, including different heat pump types and heat sources. Ground source and water source heat pumps would have higher coefficients of performance and also capital costs than air source heat pumps, the identification of the availability of suitable land and/or a water source to assess retrofit of ground or water source heat pumps for all dwelling and eligible (<45kW demand – see below) non-domestic buildings in NI is outside of the scope of this work: the more universal application of air source heat pumps is therefore utilised for the development of the tools.

Building age, type, fabric and levels of insulation were also required to be considered in addition to any practical issues that may impact upon the installation of a heat pump such as space and noise requirements, as well as the 'fit' with regulatory frameworks (e.g. planning system, Part F of the Building Regulations, and grid electrical connections).

The study brief related to buildings with a demand for heat and hot water of below 45 kilowatts (kW), in accordance with the definition of microgeneration. To identify building archetypes for energy modelling, and due to data available at the time of the study, an exercise was conducted to identify buildings with wet systems likely to fall into the <45 kW category (before any energy efficiency improvements were made). Whilst all homes are captured; this means that the tool is likely to be conservative in terms of the number of non-domestic buildings that may be suitable for the retrofit of heat pumps.

Buildings with existing air-conditioning systems providing comfort cooling that are also used to supply heat were removed from consideration in this study, as these buildings are already using a low carbon heating source. Buildings with direct electric heating or storage heaters with no air cooling were considered, as a low carbon heating source could be installed at these properties. Appropriate non-domestic buildings were considered to be those where traditional 'wet'[1] central heating systems were likely to be present e.g. small, stand-alone offices such as small medical centres or GP surgeries, (possibly within a converted home(s)); retail and cafes (potentially within a converted building) and small nursery schools or other education buildings.

The energy models for each building archetype were produced using industry standard Integrated Environmental Solutions (IES) and Standard Assessment Procedure, for a range of construction ages, to provide an annual, peak demand (in kilowatt hours) for heating and hot water, based on a peak winter day temperature in Belfast. The relevant capacity of Air Source Heat Pumps (ASHPs) was then considered to meet the full demand for heating and hot water. Due to the need to consider capital and running costs of heat pumps post fabric and services improvements, a flow rate of 55°C was considered most appropriate and cost effective for the tool when considering both domestic and non-domestic buildings. The review considered a range of heat pump flow rates to align with the suitability for low temperature, high temperature and hybrid heat pump arrangements.

[1] Traditional 'wet' central heating system such as a heating boiler with a pumped water distribution system serving heat emitters, e.g. radiators.

2. Context

2.1 Northern Ireland Energy Strategy

The Department's NI Energy Strategy – 'The Path to Net Zero Energy' (December 2021) sets out a long-term vision of net zero carbon and affordable energy for Northern Ireland by 2050. Energy accounts for almost 60% of Northern Ireland's greenhouse gas (GHG) emissions, with the principal focus of the strategy on protecting consumers, reducing the demand for energy, securing the highest levels of energy efficiency, creating new jobs by growing the green economy, sourcing energy from renewable sources instead of fossil fuels and creating a flexible, resilient and integrated energy system. Some of the targets of the strategy include:

- To deliver energy savings of 25% from buildings and industry by 2030.
- To meet at least 70% of electricity consumption from a diverse mix of renewable sources by 2030[2].

Northern Ireland's aim is to reduce energy-related GHG emissions by 56% by 2030 relative to 1990 levels in line with the Climate Change Committee's (CCC) 6th Carbon Budget.

The Energy Strategy sets out NI's commitment to introducing support for low carbon heat technologies, including heat pumps.

> *"Heat pump technology will play an important role in replacing the fossil fuel heating sources that we have committed to phasing out, although we recognise that the diversity of our building types, age and condition mean that other low carbon technologies will also play a role. We will introduce a new support scheme to help consumers switch to lower carbon forms of heat. Our first step will be to launch a pilot domestic and small business support scheme for low carbon heat in 2022/23 which will then lead to a wider rollout of support. Improving energy efficiency will be important in supporting our transition away from fossil fuels. Ensuring that buildings are as energy efficient as possible is key to the successful future expansion of the heat pump sector and cost-effective operation of heat pumps".*
>
> *"Improving energy efficiency will be important in supporting our transition away from fossil fuels. Ensuring that buildings are as energy efficient as possible is key to the successful future expansion of the heat pump sector and cost-effective operation of heat pumps. Our approach will therefore align with proposed support for energy efficiency upgrades and provide clarity about what is needed for a home to be "heat pump ready".*

2.2 NI Energy Strategy Action Plan

In January 2022, the first annual Action Plan to deliver the NI Energy Strategy was published. Five actions are noted as being potentially relevant to heat pumps:

- Action 4: Deliver £10m of funding through a new Green Innovation Challenge Fund. The fund will support green technology innovation to support the growth of the low carbon and renewable energy economy.
- Action 7: Launch a domestic energy efficiency scheme. This will deliver an area-based energy efficiency pilot scheme in 2022. It will support investment in improved energy efficiency measures in domestic buildings and inform the roll-out of a longer-term programme. It will also include access, where relevant, to low-carbon heating support.
- Action 8: Launch a non-domestic energy efficiency scheme. This will deliver a new energy efficiency support scheme for Northern Ireland businesses.
- Action 13: Review permitted development legislation for low carbon heat installations to ensure it is up to date and fit for purpose. Primarily to address the permitted development for heat pumps to align with modern standards and requirements, informed by other jurisdictions. Also, to assess any changes required for rolling out other low carbon heat technologies.
- Action 15: Develop and commence delivery of low carbon heat demonstrator projects. Deliver up to £5m of support for the decarbonisation of heat in homes, communities, businesses and delivery of low carbon heat networks.

[2] The Climate Change Act (Northern Ireland) 2022 was introduced after the Energy Strategy with a legal commitment to "*ensure that at least 80% of electricity consumption is from renewable sources by 2030*"

2.3 Future Energy Decarbonisation Scenarios NI

Future Energy Decarbonisation Scenarios Northern Ireland[3] (March 2021), prepared by DfE, sets out possible future energy trajectories, taking into consideration the geography, economy and historical energy environment of Northern Ireland (NI). Annex C of the above report contains a description of the energy research in relation to NI, including scenarios developed by the Climate Change Committee (CCC) balanced Net Zero pathway for NI and the Tomorrow's Energy Scenarios for NI by the System Operator for Northern Ireland (SONI) [Modest Progress; Addressing Climate Change and Accelerated Ambition].

For the Future Energy Decarbonisation Scenarios 'energy efficiency' theme, the assumptions for NI are:

- A 'moderate' efficiency uptake (12% heat demand reduction in homes and 27% in non-domestic buildings), loft and wall insulation installed for 100% of the 'fuel poor'.
- 'Fast' commercial uptake and 'moderate' public uptake, i.e. fast uptake of energy efficiency in other buildings.

The 'Tomorrow's Energy Scenarios[4] (TES) – Accelerated Ambition - heat' scenario, assumes a high electrification of heat, which is envisaged to be earlier and faster than in the other scenarios and with a high uptake of heat pumps, estimated at around half a million by 2050.

The report provides current figures for the proportion of households connected to the gas grid (30% in 2018) compared with the UK (85-90%) and for non-domestic buildings (5% - albeit representing 47% of gas consumption). The report recognises that, although it may have a role to play, the gas grid will not be the decarbonisation solution for many buildings in NI.

Energy performance of the existing building stock is also considered in the report noting that, in 2016/17, 49% of dwellings are within Energy Performance Certificate (EPC) Band A-C, 68% of homes use oil as the primary heating source with 72% using open/closed fires as secondary heating solutions.

2.4 Climate Action Plan, Republic of Ireland (ROI)

The Republic of Ireland Climate Action Plan (November 2021, updated in May 2022) provides a detailed plan for ROI taking decisive action to achieve a 51% reduction in overall greenhouse gas emissions by 2030 and sets a path to reach net-zero emissions by no later than 2050, as committed to in the Programme for Government and set out in the Climate Act 2021.

Within this plan, under section 14.4.6, there is a reference to how the level of Heat Loss Indicator (HLI), as calculated in Dwelling Energy Assessment Procedure (DEAP) and used to indicate which buildings are eligible for heat pump grants, should be reassessed as a criterion. Part of the NI requirement for this study is to undertake research into the Heat Loss Indicator as a criterion for the installation of heat pumps. The Plan contains the following text:

> *Under SEAI grant schemes, the current Heat Loss Indicator (HLI) criterion for heat pump installation in homes is 2.3 W/K m^2 or less. This means that homes with a HLI greater than 2.3 W/K m^2 after any building fabric works are not eligible for SEAI heat pump supports. The SEAI will carry out an action-based research study with the intention of informing and providing evidence on the optimum performance from the heat pump relative to the fabric and ventilation specification and control strategies. The objective of this research is to test the efficacy of installing a heat pump in homes with a HLI of >2.3 and ≤2.6 W/K m^2. If proven to be effective at this range of HLI, with acceptable increases in heating bills, this could allow heat pumps to be installed in many homes which:*
>
> - *Currently find it either cost prohibitive to achieve a BER B2 and achieve a HLI of 2.3 W/K m^2.*
> - *Are excessively disruptive to perform an energy upgrade.*
> - *Have been deemed ineligible by the SEAI for a grant for a heat pump installation when undertaking retrofit works in the past.*

The bullet points above are relevant for NI, i.e. improvement works to accommodate a heat pump are recognised as either cost prohibitive or excessively disruptive in some homes – hence the importance of this research to enable NI to consider these policy areas further.

[3] Future Energy Decarbonisation Scenarios North Ireland (March 2021)
[4] Systems Operator for NI (SONI), Tomorrow's Energy Scenarios Northern Ireland 2020

Further details of the ROI heat pump system grant scheme and application process are provided within Appendix C.

2.5 UK Policy & Strategy

The Energy White Paper (2020)[5] focuses on a net zero carbon future through more energy efficient buildings and a decarbonised grid. Below is a list of commitments outlined in the paper:

- The Future Homes Standard will ensure that all new-build homes are zero carbon ready.
- To maximise the number of existing homes with an EPC Band C by 2035, where practical, cost-effective, and affordable.
- That all rented non-domestic buildings will be EPC Band B by 2030, where this is cost-effective.
- Consult on regulatory measures to improve the energy performance of homes and on how mortgage lenders could support homeowners in making these improvements.
- Consult on whether it is appropriate to end gas grid connections to new homes being built from 2025, in favour of clean energy alternatives.
- Grow the installation of electric heat pumps from 30,000 per year to 600,000 per year by 2028, supporting up to 20,000 jobs by 2030.

In relation to growing the number of heat pump installations, the UK Government has launched the Boiler Upgrade Scheme to provide £5,000 capital grants to support the installation of Air Source Heat Pumps (ASHPs) in domestic and non-domestic buildings up to a capacity limit of 45 kWth. The scheme will not support hybrid systems.

'The Ten-Point Plan for a Green Industrial Revolution[6]' focuses on 'greener' buildings, as follows:

- Homes built to the Future Homes Standard will have 75–80% lower carbon dioxide emissions than those built to current standards.
- Green home finance initiatives could help to improve the energy efficiency of around 2.8 million homes, improving approximately 1.5 million homes to EPC Band C standard by 2030.

The UK Heat and Buildings Strategy (October 2021)[7] sets out a policy approach with a set of five core principles to guide action in the 2020s and longer-term transformation to Net Zero:

- Consider the heating system in the context of what is most appropriate for the whole building, as well as considering local and regional suitability and how best to manage system-level impacts.
- Ensure that regional, local and national decisions can be informed by the latest data and research, and work with industry to refine processes and technologies to deliver value for money.
- Accelerate 'no and low regret' actions by prioritising the improvement of buildings with low energy performance and high-carbon emissions, futureproofing new-builds to avoid the need for later retrofitting, adopting a fabric-first approach to improve building thermal efficiency, increasing the performance of products and appliances, ensuring climate change resilience by mitigating risks of overheating and poor air quality, building the market by developing technical expertise, growing the workforce, and expanding the UK's manufacturing capacity and capability.
- Balance certainty and flexibility to provide both stability for investment and an enabling environment for different approaches to be taken to address different buildings. Provide long-term signals to investment by setting requirements and embedding flexibility in how they are achieved, so businesses and the public can prepare to decarbonise in a way that suits them and maximise the opportunities this presents, including investing in training in greener skills.
- Target support to enable action for those in most need to ensure that policies support those who are hardest hit by COVID-19, such as small businesses and the fuel poor. Using taxpayer money efficiently to transform public sector buildings and improve the support and protection available for consumers.

[5] Energy white paper: Powering our net zero future, BEIS
[6] The Ten Point Plan for a Green Industrial Revolution
[7] HM Government – Heat and Buildings Strategy

2.6 Research into the Future of Energy Efficiency Policy in Northern Ireland

To inform energy efficiency policy in NI, Arup[8] carried out the NI building stock analysis for both dwellings and non-domestic buildings. The analysis outcomes included defining the dwelling and non-domestic building types (and estimating the number of buildings per each type), the categorizing of building stock per tenure type, central heating type and the adoption of cavity wall insulation per tenure type and location.

The total investment costs required for the intervention measures were calculated using cost data collected from suppliers and the Energy Savings Trust (2020) for various building tenure. Interventions such as domestic hot water saving measures, building energy operation, cavity wall insulation, solid wall insulation, domestic loft insulation, domestic floor insulation, domestic windows - triple glazing, low temperature heating system and lighting efficiency were all evaluated.

Arup's modelling approach is shown in Figure 1.

Figure 1: Extract (Figure 7) Outlining Arup's Modelling Approach

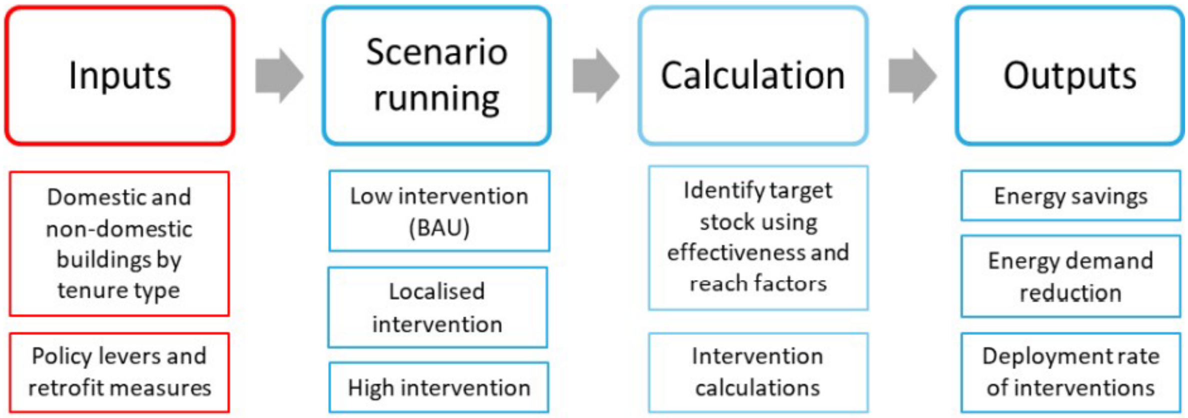

Figure 7: High level methodology diagram for modelling process.

The outcomes from modelling confirmed that, *"a dramatic change in policy extent and funding levels is required for NI to put building energy performance in line with the UK's net zero carbon emissions commitment. The modelling indicates that a peak of retrofit measures for up to 30,000 buildings per annum is the minimum necessary to align with the UK's 2030 energy efficiency target. To align with 2050 net zero commitments, it is estimated that policies would need to drive an annual peak of retrofits for over 50,000 buildings within the next decade."*

One of the proposed approaches to energy efficiency in buildings included, *"Provision of technical models to support a targeted roll-out'*, which corresponds to the purpose of this policy tool. According to Arup, the outcomes should be, *'a solid foundation of technical understanding of the archetype-specific challenges, costs and benefits associated with the 'whole house' plans necessary for net zero ambitions including the individual interventions and the most appropriate logical order for phased, 'no regrets' approaches."*

Regarding an energy efficiency target, Arup recommended that, *"Possible suitable metrics include energy consumption per unit floorspace (e.g. kWh/m²/yr) or unit of economic output (kWh/£GDP/yr). Of these two, we consider that the rate per unit floorspace is most directly related to the policy purpose under consideration, which is to improve the energy efficiency of buildings. At the property level, there is a call to reform monitoring metrics and certification to reflect real-world performance, rather than modelled data (e.g.* Standard Assessment Procedure *). Accurate performance testing and reporting must be made widespread, committing developers to the standards they advertise (CCC, 2019b)."*

In this study, minimum energy efficiency standards (MEES) were modelled to provide a significant proportion of the projected energy savings. This type of lever has already been implemented in England and Wales and is proposed in Scotland. According to this study mandatory MEES are an approach to driving energy efficiency investment in tenanted building stock. Section 2.7 of the Arup report contains a brief review of evidence of experience of MEES to date and their potential to be applied in NI.

Although the type and tenure of non-residential buildings was taken from the Land & Property Services (LPS) valuation list provided by the Department of Finance (2018), the size of buildings was not available. Also, the

[8] Research into the Future of Energy Efficiency Policy in Northern Ireland | Department for the Economy

precise data about the split among small and medium sized enterprises (SMEs) and Large Enterprises was not available. The assumption was made based on the Inter Departmental Business Register published by Northern Ireland Statistics and Research Agency (NISRA) (2019), where the data shows that only 0.4% of total enterprises in NI employ over 250 employees. However, from the available information it was not possible to confirm the number and size of the buildings.

It should be noted that the dataset used to analyse insulation levels in dwellings does not distinguish between different types of wall insulation or the types of walls properties may have. The data relating to loft insulation could be more granular regarding the thickness of insulation different properties have installed. For this analysis, assumptions were used to estimate the proportion of properties that already have loft insulation and could benefit from further improvement.

The total investment costs were based on publicly available cost data from EST provided as UK averages. For this study the cost of purchasing heat pump systems have been obtained by a Quantity Surveyor (specialising in mechanical and electrical services) liaising with a range of heat pump manufacturers and suppliers in Northern Ireland with typical installation costs obtained from liaising with a Contractors based in Northern Ireland, refer to section 11.

The UK Heat and Buildings Strategy (October 2021) sets out a policy approach with a set of key commitments to guide action in the 2020s and longer-term transformation to Net Zero, including:

> *“Rebalancing energy prices to ensure that heat pumps are no more expensive to buy and run than gas boilers. Clean, cheap electricity is an everyday essential. We have seen the impact of overreliance on gas pushing up prices for hardworking people but our plan to expand our domestic renewables will push down electricity wholesale prices. However, current pricing of electricity and gas does not incentivise consumers to make green choices, such as switching from gas boilers to electric heat pumps. We want to reduce electricity costs so when the current gas spike subsides, we will look at options to shift or rebalance energy levies (such as the Renewables Obligation and Feed-in-Tariffs) and obligations (such as the Energy Company Obligation) away from electricity to gas over this decade.”*

2.7 'BER Advisory Report' - SEAI

As set out in 2.3, requirements are introduced in the UK related to the energy performance of the existing building stock, as measured by Energy Performance Certificates (EPCs). Similar to the UK, Building Energy Rating (BER) assessments in Ireland produce a BER certificate and an advisory report and the advisory report provides a personalised roadmap for homeowners on how to upgrade their home to a target energy rating, or better. In Ireland, recommendations are in line with the targets within the Climate Action Plan. As in the UK, the advisory report includes:

- Colour coded performance indicators for the home's current status and its potential following the installation of recommended upgrades.
- A recommended package of upgrades to improve the dwelling to a target of B2 or better.
- A 'fabric-first' approach to achieving an improved BER where appropriate.
- Approximate cost indicators and grant availability for individual upgrades.
- Clearer, more targeted advice on simple measures that may be considered by the homeowner in order to improve the energy efficiency of their home.

What is different in Ireland is the generation of a Heat Loss Indicator figure. The Heat Loss Indicator (HLI) output is a summary value for the building in the current situation and when all proposed measures are in place. There is no breakdown of how much each energy efficient measure contributes towards lowering the HLI. For a given home a higher HLI figure would require a greater heating demand and a larger heat pump capacity resulting in greater strain in the local electricity grid.

While the majority of advisory reports will recommend measures to achieve a B2 energy rating or better, not all dwellings can achieve a B2, for example heritage buildings. While a B2 may be difficult to achieve for some dwellings, any improvement in the BER will be worthwhile.

Recommended steps from the BER Report to upgrade the energy efficiency of homes are to:

- Insulate the building.
- Assess and upgrade the heating system to a heat pump.
- Generate energy from renewables.

If more significant works are not possible, there are simple measures that can be taken such as draught-proofing, replacement of inefficient lighting, insulation of the hot-water cylinder and lowering the cylinder thermostat to 65°C.

2.8 Comparison of DEAP vs SAP 2009 Regarding Heat Loss Indicator

The Heat Loss Indicator (HLI) that is shown as an output in the Domestic Energy Assessment Procedure (DEAP) software used in Ireland is the equivalent of heat loss coefficient (HLC) in the Standard Assessment Procedure (SAP) calculations measured in Watts/Kelvin. (W/K) utilised in the UK, including Northern Ireland. The W/K output is based on fabric and ventilation losses. Fabric losses are calculated for all thermal elements plus the thermal bridge losses. Ventilation losses are mainly based on the infiltration rate and wind speed from weather data files.

Fabric Heat Loss[9] (W/K) = Sum (A*U)

Thermal bridges[10] = Sum (L*Psi)

Ventilation Heat Losses[11] = 0.33 *(Sum of monthly Effective ACH) * Volume

To be more specific, the Heat Loss Indicator (HLI) $= \frac{\text{Fabric Heat Loss} + \text{Ventilation Heat Loss}}{\text{Floor area of the dwelling}}$ [W/Km²]

DEAP and SAP use the same methodology for calculating the HLI or HLC The only difference between the two sets of software is that DEAP shows this as an output and rounds up the numbers, whereas the SAP figure is more exact (up to 2 decimal points) and must be extracted from the calculations manually (not a shown output).

[9] A = Area, m², U = Thermal Transmittance, W/m²/K
[10] L = Length, Psi = Psi value (linear thermal heat transmittance), W/m/K
[11] ACH = Air Change Rate

There are two forms of SAP software, SAP (full) which is used for calculations related to new build homes, and RdSAP (reduced) which is a methodology used for existing homes. Only full SAP calculations and not Reduced Data SAP (RdSAP) can provide the HLC number. The HLI cannot be calculated where just EPC output data is held. Where schemes have metrics which could require use of different software for assessment e.g. the Microgeneration Certification Scheme has a cut-off level of 45 kW installed capacity which would apply to small businesses and dwellings alike, this inconsistency of output is a frustration and suggests a need for an agreed metric to be included, perhaps on EPCs for identifying the readiness of a building for heat pumps.

To obtain a kWh figure for space heating from both software, more inputs will be required. The most important are useful gains (internal and solar) and average external temperature per month.

A limitation that DEAP excel interface has is that it doesn't automatically pre-fill some inputs when basic selections are made. For example, in SAP there is a database with heating systems that have default values. This may also be true in a developed DEAP software available in the market, but it is not a function in the simple excel tool.

An example of building with a HLI > 2.6 W/K-m^2

A terraced house of 100 m^2 floor area, 2-storey height, has a HLI > 2.6 W/K-m^2 with all of the following:

- A suspended sealed uninsulated floor.
- An uninsulated solid brick wall, with draught-stripped windows and doors, no drylining.
- A chimney and 3 intermittent fans.
- Old, double-glazed windows (pre-2006).
- 50 mm of insulation at roof joists.

A simple run of calculations using DEAP software shows that this building would require the following energy improvements to have an HLI < 2.0 W/K-m^2:

- A sealed chimney with no continuous ventilation.
- Drylined walls.
- Double-glazed windows (installed during or after 2006).
- 270 mm of insulation at roof joists.

The same characteristics won't work for a smaller building e.g. 90 m^2, as the HLI goes just above 2.0 W/K-m^2, but still less than 2.3 W/K-m^2.

The ROI Climate Action Plan seems to challenge the upper limit of the Heat Loss Indicator that is required for a heat pump grant. Any increase in the HLI threshold would favour smaller dwellings in terms of energy efficiency. It is also worth noting that energy costs vary between ROI and NI, including electricity costs and the price of oil and gas. This means that, whilst lessons can be learned from this approach, the actual figures within the report will be different in NI.

3. NI Specific Research

The Energy Group within the Department for the Economy (DfE) in Northern Ireland commissioned KPMG to undertake research on the heat pump sector in Northern Ireland[12].

The aim of the research was to understand the existing heat pump sector in Northern Ireland, current capacity of the supply chain (including manufacturers, suppliers, wholesalers, distributors and installers to the commercial and domestic market) and make recommendations to the Department on potential actions that would support and promote sustained, long-term growth of the heat pump sector. A survey was planned to be the key element of this research and the primary source of first-hand information on the heat pump sector in Northern Ireland. The findings of the survey are intended to help the DfE to consider evidenced based policy and identify appropriate support mechanisms for the heat pump sector.

The survey questions are useful in identifying the key topics when considering retrofitting heat pumps and providing evidence to help consider how the suitability of existing buildings for heat pumps can be assessed.

The KPMG survey, identifies some of the key information needed to undertake a detailed assessment of the heat pump sector in NI including:

- Relevant standards, including acoustic considerations, which apply to good quality heat pump retrofits.
- Basic building data (i.e. identifying the quantity, age, type of building, size, current heating fuel and type).
- Types of heat pump and their performance.
- Heat pump efficiencies.
- Issues related to cost including the running costs and capital cost of installations.

The above topics are explored in this Literature Review.

[12] KPMG - Heat Pump Research

4. UK Research

A study[13] funded by the Department for Business, Energy and Industrial Strategy (BEIS), is the Electrification of Heat (EoH) Demonstration Project. This project is managed and coordinated by Energy Systems Catapult in partnership with Delta-EE and Oxford Computer Consultants. The EoH project seeks to enable a better understanding of the technical and practical feasibility of a large-scale rollout of heat pumps into existing British homes.

Research suggests the slow uptake of heat pumps is partly driven by economics but also due to challenges in current domestic consumer proposition, such as the varying thermal efficiency of the housing stock and extremely high market penetration of gas boilers. To date, most heat pumps in Britain have been installed in large, off-gas grid homes, where there are fewer barriers to deployment. They are also being predominantly installed by early adopters, housing developers and social landlords. The EoH project seeks to better understand these barriers and provide evidence on the feasibility of a large-scale rollout of heat pumps, by seeking to increase confidence in the technology to levels that could enable strategic decisions on the future of heat networks.

To support this, the project aims to:

- Develop, test and evaluate products and services that increase the appeal of heat pumps and identify optimal solutions for a wide range of homes.
- Demonstrate that heat pumps, including gas-electric hybrids, can deliver high consumer satisfaction across a wide range of consumers in Great Britain.
- Demonstrate the practical and technical feasibility of heat pumps, including gas-electric hybrids, across Great Britain's diverse housing stock, as well as identifying the costs.
- Capture learning from the project to help improve awareness across the renewable heating supply chain, raise acceptance and support wider deployment of heat pumps in Great Britain.

The project installed and monitored 742 heat pumps in housing archetypes that were representative of the British housing stock and household socio-economic groups, with the majority of the dwellings on the gas grid. It should be noted that a much smaller proportion of dwellings in Northern Ireland are connected to the gas grid than in other parts of the UK.

The recruitment and installation phase of the EoH project ran from July 2020 through to October 2021. The key points of interest for the purposes of this report are that low temperature and high temperature Air Source Heat Pumps are being tested, along with Ground Source Heat Pumps and Hybrid solutions. The residential dwelling types include Detached, Semi-detached, End-terrace, Mid-terrace and apartments. Property age bands of the properties being tested include pre-1919, 1919-1944, 1945-1964, 1965-1980, 1981-1990, 1991-2000 and 2001 onwards.

The EoH demonstrator has found no particular type or age of property that is unable to have a successful retrofit heat pump installation although there have been greater, but manageable challenges in successfully designing heat pump systems for older homes. The report does not make it clear what made the retrofits 'successful', whether this was the achievement of a technical solution or whether there were any economic parameters applied.

[13] Electrification of Heat' (EoH) UK Demonstration Project

5. Heat Pump Regulatory Framework and Systems

In September 2018, a report[14] was commissioned by the Greater London Authority (GLA) to support the development of an evidence base to inform the implementation of London Plan policies on the decarbonisation of heat and the final London Environment Strategy publication. As part of developing this report, respondents to a survey rated noise impact of heat pumps as one of the higher risks preventing wider adoption of heat pump installation. Key findings were that all air source heat pump configurations were considered to have potential noise impacts, but particularly in medium density apartment buildings. In the same survey the visual impact of heat pumps was also identified as a deterrent to installation.

Whilst subject to certain conditions, domestic air-source heat pump retrofits are considered a Permitted Development in NI, albeit with a current requirement for a 30-metre space to the closest dwelling house. This 30 m limit is likely to mean an application for planning permission will be required for almost all domestic heat pump retrofits. For apartments and non-domestic buildings in NI (which sit outside of Permitted Development), an acoustic assessment is required to be included within the planning pack for consideration of planning permission. There will be a time and cost associated with obtaining the necessary planning permission.

As part of an application for planning permission, approvals are likely to be required in relation to the siting of heat pumps that are proposed to be located on walls facing roads or in sensitive settings related to heritage, such as listed buildings etc. Back gardens or the rear of / hidden spaces related to commercial buildings are therefore the only likely locations to install heat pumps in domestic or non-domestic buildings. This introduces constraints to heat pump retrofit, especially for homes and small businesses located in terraced streets, where back gardens or spaces to the rear of buildings may be non-existent or very small. Siting rules are listed under the conditions in the NI General Permitted Development Orders (GPDOs), see section 5.1 of this report.

5.1 Planning

The Planning (General Permitted Development) Order (Northern Ireland) 2015[15] confirms that retrofit of Air Source Heat Pumps (ASHPs) to dwelling houses in NI is a Permitted Development, subject to conditions. The General Permitted Development Order (GPDO) provides the requirements for the provision of the installation, alteration, or replacement of an ASHP within the curtilage of a dwelling house (Figure 2).

Figure 2: Extract Outlining General Permitted Development Order in NI

Permitted development	***G.***	***The installation, alteration or replacement of an air source heat pump within the curtilage of a dwelling house.***
Development not permitted	*G.1*	*Development is not permitted by Class G if—* *(a) it would result in the presence within the curtilage of more than one air source heat pump;* *(b) any part of the air source heat pump would be less than 30 metres from a dwelling house (other than the dwelling house on which the air source heat pump is being installed, altered or replaced);* *(c) any part of the air source heat pump would be situated on land forward of a wall which—* *(i) faces onto a road; and* *(ii) forms either the principal elevation or a side elevation of the original dwelling house;* *(d) in the case of a dwelling house within a World Heritage Site or conservation area any part of the air source heat pump faces onto and is visible from a road;* *(e) the external unit of the air source heat pump would exceed 2 metres in height;* *(f) the air source heat pump would be installed on a roof;* *(g) the air source heat pump would be situated within the curtilage of a listed building unless listed building consent for the development has previously been granted.*
Conditions	*G.2*	*Development is permitted by Class G subject to the following conditions—* *(a) the air source heat pump would be used to provide heat for use within the curtilage of the dwelling house; and* *(b) when no longer used to provide heat it shall be removed as soon as reasonably practicable.*

[14] Low Carbon Heat: Heat Pumps in London, Greater London Authority
[15] The Planning (General Permitted Development) Order (Northern Ireland) 2015

The NI (2015) GPDO differs from the England GPDO[16] and the main key differences are:

- Heat pump installation must comply with the Microgeneration Certification Scheme (MCS) planning standards (NI does not reference MCS).
- An external air source heat pump unit volume must be under 0.6m^3 (as opposed to a 2 m height restriction in NI).
- Air source heat pumps must be installed at least 1 metre from the building boundary (as opposed to 30 metres from the dwelling house in NI.
- Air source heat pumps must not be pitched on a roof (as in NI) but can be sited at least 1 m from the edge of flat roof.
- The heat pump must be used ***solely*** for heating (NI doesn't specifically preclude use of the heat pump for cooling).

There is significant alignment with the England GPDO in both Scotland and Wales. The Wales GPDO[17] differs only to England's GDPO in that a distance of at least 3m from the building boundary is required and, instead of a unit volume under 0.6 m^3, the external compressor unit must be under 1 m^3 in volume. The Scotland GPDO[18] differs to England's GDPO in that any heat pump cannot protrude more than 1m from an external wall, roof or chimney of a dwelling and cannot exceed 3 metres in height.

One of the key purposes of this policy tool is to provide an indication of those buildings that would be suitable or unsuitable for the retrofit of ASHPs (whether they are low temperature, high temperature or some form of hybrid heat pump). Some of the NI GPDO conditions are very specific in relation to the shape, position and location of the dwelling house, as well as the surrounding environment, and it is therefore difficult to accurately identify how some of these conditions will impact on the feasibility of an ASHP retrofit across the domestic sector.

Perhaps the most significant conditions are:

- The ASHP must be more than **30 metres** from a dwelling house (other than the dwelling house on which the ASHP is being installed). This condition is likely to render unsuitable all terraced, and almost all semi-detached and detached houses (unless they have relatively substantial gardens).
- The retrofit of the ASHP is to be located to the rear of dwelling houses and not on roofs.
- Each dwelling house is to be restricted to one ASHP of no more than 2 m in height. More than one ASHP would require a planning application.
- All listed buildings to achieve listed building consent.
- Under Section 2 of the GPDO, the interpretation of a "dwelling house" does not include a building containing one or more flats, or a flat contained within such a building. Therefore, apartments are not included within the Order and, along with non-domestic buildings, planning permission is required.

The above conditions are likely to hinder the installation of heat pumps which are aimed at helping NI meet its objectives in respect of climate change. As a result, the GPDO conditions will most likely need to be reviewed in the near future which corresponds to Action 13 of the NI Energy Strategy Action Plan (section 2.2 of this report) which is to *"*review permitted development legislation for low carbon heat installations to ensure it is up to date and fit for purpose*"* and notes that this is *"*primarily to address the permitted development for heat pumps to align with modern standards and requirements, informed by other jurisdictions."

A news article[19] written by Tom Lowe (June 2021) which BEIS has responded to, points to the types of issues that this policy tool would need to consider.

The issue raised is highlighted in bold below, with the UK Government response thereafter. The comments do not necessarily reflect the position within Northern Ireland.

- **"Generate noise which breaches legal limits"** – *"Modern, efficient heat pumps are quiet and generally no louder than average ambient background noise levels. To be allowed under permitted development, any heat pump must be installed in compliance with the Microgeneration Certification Scheme Planning Standard MCS-020 which stipulates that noise levels for an air source heat pump must be at or below 42 decibels one metre distance away from any habitable room of a neighbouring property. These standards are kept under review to ensure they continue to be fit for purpose."*

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[16] The Town and Country Planning (General Permitted Development) (England) Order 2015
[17] The Town and Country Planning (General Permitted Development) (Amendment) (Wales) Order 2012
[18] The Town and Country Planning (General Permitted Development) (Scotland) Amendment Order 2016
[19] Major challenges in persuading homeowners to install heat pumps, government admits | News | Building

The key issues for consideration in respect of retrofitting heat pumps[20] in NI are:

- The distance from curtilage - It should be noted that in Wales the distance is 3m based on noise limits.
- The GPDO excludes apartments which as a result, heat pump retrofit will not be suitable for a significant proportion of NI's residential building stock. Based on GIS data from 2022 the percentage of flats / apartments within the residential building stock is approximately 11%.

Regardless of whether the work to be carried out is a Permitted Development or not, work must comply with the Building Regulations. Building Regulations relate to the building work itself and not the permission to carry out the work. Therefore, for the retrofitting of heat pumps, and associated works e.g. external insultation, there is a requirement for a Building Control application including the submission of full plans, which will incur a fee.

The Department of Finance (DoF) is responsible for Building Regulations in NI. Building Regulations (Part F) is covered within two 'Technical booklets' which cover the conservation of fuel and power in dwellings and non-dwellings:

- Building Regulations (Northern Ireland) 2012, Guidance, Technical Booklet F1 - Conservation of fuel and power in dwellings (Technical Booklet F1), DFP, October 2012[21].
- Building Regulations (Northern Ireland) 2012, Guidance, Technical Booklet F2 - Conservation of fuel and power buildings other than dwellings (Technical Booklet F2), DFP, October 2012[22].

Technical Booklets prepared by the Department of Finance set minimum energy performance standards and provide practical guidance on the technical requirements of the Building Regulations (2012) in Northern Ireland.

Section 3 in Technical Booklet F1 and F2 is relevant to existing buildings. Section 3 makes provision where there is a change to a 'controlled service' and subject to procedures and standards as set out in the Domestic Building Services Guide (DBSG) and the Non-Domestic Building Services Guide (NDBSG) relating to installation, plant efficiency and commissioning.

The relevant detail from Technical Booklet F1, Section 3.29 reads as follows:

> *"Where the work involves the provision, replacement or extension of a fixed building service, the service should be provided and installed in accordance with the provisions and standards given in the Domestic Building Services Compliance Guide."*

The efficiency claimed for the fixed building service should be based on the appropriate test standard given in the Domestic Building Services Compliance Guide and the test data should be independently certified by an accredited body. Where a particular technology is not covered by this guide, it should be demonstrated that the proposed technology has a performance that is equivalent to a reference system of the same type whose details are given in this guide. Also, the commissioning procedures to be followed are set out in the Guides[23].

Technical Booklet F1, Section 3 requires that where heating systems are replaced, the efficiency of the replacement should be no less than that which is being replaced. Given SCOPs of 2.5, the retrofit of a heat pump should not present any compliance issues related to achieving required efficiencies or carbon emissions performance.

Section 3.37-3.40 of F1 require that retrofit heat pumps should be commissioned by testing and adjustment, as laid out in a Commissioning Plan to be submitted to the District Council at plans submission stage to inform their checking regime. The plan is to identify the fixed building services that need to be tested and confirm which tests will be carried out. Once the installation is complete, written notice is to be provided to the District Council not more than 5 days after completion, to confirm commissioning is completed, the notice being signed by a suitably qualified person. The notice should confirm that the Commissioning Plan has been followed and that every system has been inspected in an appropriate sequence and to a reasonable standard and that the test results confirm that the performance is reasonably in accordance with the design requirements. Failure to provide the commissioning notice may mean that the District Council is unable to issue a completion certificate.

Given that, in potentially many cases, the retrofit of heat pumps will be combined with improvements to building fabric, the booklets also set out the required standards[24] for the replacement of controlled fittings (e.g. the whole unit of a window, roof window, rooflight or door, including the frame) and for the renovation of thermal elements e.g. standards for thermal transmittance – known as 'U-values').

[20] It should be noted that different conditions apply to the installation of Water Source Heat Pumps (WSHPs) and Ground Source Heat Pumps (GSHPs).
[21] Technical-booklet-F1-Conservation of fuel and power in dwellings-October-2012
[22] Technical-booklet-F2-Conservation-of-fuel-and-power-in-buildings-other-than-dwellings-October-2012
[23] Both the UK Domestic and Non-Domestic Building Services Compliance Guides are withdrawn as of 2022.
[24] Table 3.1 in Technical Booklet F1.

Booklets F1 and F2 set out standards for such replacements and calculation methods (including for where the external appearance of the building may prevent standards from being achieved). Evidence of compliance is to be provided to the District Council. For thermal elements, a Window Energy Rating (WER) declaration from a certification scheme that provides a quality assured process and supporting audit trail (from calculating the performance of the window to installation) is suitable evidence.

For the renovation of a thermal element, provision is made where special considerations apply to buildings of historical or architectural value, to buildings of traditional construction that need to “breathe” and, where upgrading to the above standards is not technically or functionally feasible, or would not achieve a simple payback of 15 years or less.

Part F of the Northern Ireland Building Regulations is relevant to this policy tool as, when considering data sources to inform modelling of the building stock, standards set out in different versions of Part F provide an accurate building specification for buildings constructed at different times. These specifications are employed in our modelling.

Technical Booklet F1 Appendix C gives guidance on the cost effectiveness of insulation measures when undertaking various types of work on a thermal element. The Technical Booklets were last published in 2012, the implications being that prices of cost-effective measures may be obsolete. The measures included in this policy tool have been assessed for 2022 prices in relation to Northern Ireland[25].

Although as of 2022 there are differences, before the recent updates of guidance in England and Wales, the U-values for renovated thermal elements were the same as in NI.

5.2 National Electricity Distribution

In the ‘Minutes of Evidence Report’ dated 29th September 2021[26], the Committee for the Economy considered several questions raised about grid connections and related costs. It is anticipated that there will be a need for many more electricity supply connections and an associated need to invest in the grid to make sure it can accommodate further renewable energy equipment.

One of the principles in the NI energy strategy focuses on creating a flexible and integrated energy system, of which the electricity grid will be an important part. It is not just about investing in the grid, which is needed, but about how better use can be made of the grid. Also, it is noted that even though there will be some reduction in electricity demand due to energy efficiency measures, there is likely to be increased demand from electric vehicles and the electrification of heat.

Northern Ireland Electricity Networks collaborated with Northern Ireland Housing Executive (NIHE), the Centre of Sustainable Technologies at Ulster University and Element Energy Consultants to produce a report entitled Networks for Net Zero, Delivering a sustainable energy system for all (2021)[27].

This report sets out how NIE Networks can facilitate increased renewables on the network and how it can enable an increasing uptake of low carbon technologies such as electric vehicles, solar photovoltaics and electric heat pumps. The report presents independent modelling (carried out by Element Energy Consultants) that has been undertaken to examine the potential pathways to decarbonisation and presents inputs from academia who are engaged with studies and trials into many aspects of the low carbon transition.

The report provides some useful statistics, including for example:

- 68% of household central heating systems are oil fired compared to 24% with gas central heating and 8% other central heating including solid fuel, electric and dual fuel systems.
- 49.2% of electricity consumption in Northern Ireland is already provided from renewable sources.

The report presents NIE Networks’ strategy to support the creation of a sustainable energy system for the future in Northern Ireland. The document describes a range of scenarios and provides national level costs for connecting low carbon technologies to the NI electricity grid, including the mass uptake of heat pumps (the impact on the grid can’t be considered in isolation from other measures such as Electric Vehicles and Solar PV).

As part of this study, the information available in respect of the process for connecting low carbon technologies was reviewed. The key findings are that, even if the installation is suitable, there is both a cost and time requirement

[25] Building Regulations 2010.
[26] Energy Strategy. Department for the Economy. 29 September 2021.
[27] Networks For Net Zero, Northern Ireland Electricity Networks.

of connecting a heat pump to the national grid, though for some properties these connection costs are likely to higher than for others.

Heat Pumps of larger capacity (e.g. for detached houses, non-domestic premises or centralised heat pumps for apartment buildings), possibly requiring split systems and 3-phase supplies will be more likely to require the 'apply to connect' process than installations that would be typical in terraced and/or semi-detached houses. These larger systems would likely incur higher fees and longer lead-in times before installation.

There are opportunities to identify the most competitive prices for delivering elements of the work. Due to the introduction of competition into the UK electrical distribution market, contestable works (which include the installation of cables, substations and other plant associated with a new connection) can now be delivered by a certified Independent Connections Provider (ICP). Following an initial application to Energy Networks Association (ENA), those wishing to connect can either appoint the Distribution Network Operator (DNO) for all of the works, or just the non-contestable element (certain types of reinforcement works that can affect the day-to-day operation of DNO network). Due to the sensitivity and potential impact of these works, the DNO will only complete these works themselves. Further details of the Northern Ireland electricity networks application process are outlined within Appendix B.

In discussions with the DNO, it is established that there has been relatively little activity in relation to heat pump installations to-date in NI and therefore insufficient evidence is available in relation to specific or average costs of connection. What is clear is that for Great Britain there is a greater socialisation of the costs for grid connections than for NI and this could introduce significant barriers to large-scale uptake of heat pumps.

A report produced by Delta Energy & Environment Ltd, on behalf of the Department for Business, Energy & Industrial Strategy (BEIS)[28] investigates the feasibility of connecting electric heating technologies (including low and high temperature air source heat pumps, ground source heat pumps, direct electric heating and storage heaters) in rural off-gas grid dwellings.

This report presents an estimation of the number of rural off-gas grid houses in England & Wales that could have electric heating systems installed. The weighting factors for rural off-gas grid houses in England was derived from English Housing Survey (EHS) 2016 data. *"The suitability of electric heating systems for off gas grid homes are evaluated using an Excel based model with inputs from the Cambridge Housing Model (CHM), the most recent English Housing Survey and Living in Wales 2008 survey data."* Further information about the CHM is available on the BEIS website[29].

The study considers the technical feasibility of connecting electric heating technologies at a dwelling level and at the level of the local electricity network. The implications of electric heating in rural areas on the low voltage network has been tested by considering the limitations of the low voltage distribution network based on distribution network data.

The suitability of electric heating technologies at the dwelling level has been tested by considering thermal (e.g. different levels of insulation against baseline) and electrical (e.g. available current [amperes per phase]) constraints.

The report concludes that 70% of dwellings in England and Wales are suitable for low temperature ASHPs with their current state of insulation. This climbs to 80% with loft insulation, 85% with loft and floor insulation and 90% with loft and wall insulation.

In homes designated as 'technically suitable' and where it is assumed that heat pumps with the highest COP are installed in homes as a matter of preference, the report finds that there is a relatively small difference in the low voltage feeders overloading between those with existing insulation levels (20%) and those fitted with full loft and wall insulation (25%). This is because the reduction in heating load per dwelling is being counteracted by an increased percentage of houses where electrification is technically possible. For example, in both the existing insulation levels scenario and the wall & loft insulation scenario, 10-13% (average peak winter day scenario) of feeders are overloaded. However, the percentage of dwellings electrified has increased from 86% to 95%. The study identifies that for the 1-in-20 peak winter day scenario, where ASHPs are augmented with direct electric heaters to meet the additional heat load, feeder overload more than doubles, to 33%. This is due to the additional electrical load by use of the supplementary direct electric heaters.

A larger amount of variation in feeder characteristics is identified as part of the Delta report e.g. some feeders are able to have high levels of electrification without overloading the network, whereas others would require significant reinforcement. For the 1-in-20 scenario where both insulation scenarios are shown, representing the highest and lowest percentage of homes where electrification is technically possible, over 40% of feeders need to be treated to

[28] Technical feasibility of electric heating in rural off-gas grid dwellings
[29] Cambridge Housing Model and User Guide

reach 50% electrification. The overall percentage of homes that can be electrified within current network capacity plateaus at 60%, 30% lower than in the average peak winter day scenario.

There are several options available to reduce the peak demand due to electric heating on the low voltage network. These include improving the efficiency of heat pumps, especially under cold weather operation regimes, increasing heat pump capacity to meet the 1-in-20 peak load without the need for additional direct electric heating, or optimised operation to reduce heat pump cycling and peak shifting using smart controls and/or thermal stores or battery storage. A reduction in peak load of 70%, through a combination of the aforementioned measures, could reduce the percentage of feeders needing reinforcement from approximately 30% on a 1-in-20 peak winter day to under approximately 10%.

Whilst there are obvious issues in taking direct data from this study (the building stock composition and insulation levels are likely to vary between NI, England and Wales), this report is useful when looking at the relatively small coverage of the gas network in NI and the desire for NI to quantify the number and degree of readiness of off-gas grid homes to receive low and high temperature heat pumps, direct electric heating and storage heaters.

5.3 Adopted Study Approach

The national-level assessment tools developed in this study highlight planning requirements based on the proportions agreed with the client for three different restriction limits (Table 1 - Table 4). For instance, if the heat pump location from the nearest threshold is set to 1 m (currently 30 m in NI), it has been assumed that 95% of the detached dwellings would not require planning permission to install a heat pump. These proportions can be amended in the tools for further analysis and decision-making.

Table 1: Planning Requirement Threshold and Proportions for Domestic Buildings (National Level Tool)

Built Form	Likelihood of Avoiding Planning Permission Requirement for Different Planning Restriction Limits. i.e. 95% => Likely to Not Requiring Planning		
	1 m	3 m	30 m
Detached	95%	75%	10%
Semi-Detached	90%	50%	0%
Mid-Terrace	75%	33%	0%
Flat	33%	0%	0%
Bungalow	95%	75%	5%

Table 2: Planning Requirement Threshold and Proportions for Non-Domestic Buildings (National Level Tool)

Built Form	Likelihood of Avoiding Planning Permission Requirement for Different Planning Restriction Limits. i.e. 95% => Likely to Not Requiring Planning			
	0 m	1 m	3 m	30 m
Office	95%	95%	75%	10%
Restaurant / Café	95%	50%	0%	0%
Retail Shop	95%	50%	0%	0%
School	95%	95%	75%	10%

The self-assessment tools utilise the 30 m restriction limit currently enforced in NI as presented in the following tables.

Table 3: Planning Requirement Threshold for Domestic Buildings (Self-Assessment Level Tool)

Built Form	Planning Restriction Limit
	30 m
Detached	A Planning Application Is Likely To Be Required
Semi-Detached	A Planning Application Is Highly Likely To Be Required
Mid-Terrace	A Planning Application Is Highly Likely To Be Required
Flat	A Planning Application Is Highly Likely To Be Required
Bungalow	A Planning Application Is Likely To Be Required

Table 4: Planning Requirement Threshold for Non-Domestic Buildings (Self-Assessment Level Tool)

Built Form	Planning Restriction Limit
	30 m
Café	A Planning Application Is Very Likely To Be Required
Office	A Planning Application Is Likely To Be Required
Retail	A Planning Application Is Very Likely To Be Required
School	A Planning Application Is Likely To Be Required

Costs associated with obtaining planning permissions or applications to Building Control have not been considered within the policy tool costs.

This policy tool does not contain any specific information on available external space limitations with regard to locating the external heat pump unit. The tool assumes that there will be a vacant section of external wall where a heat pump can be located, e.g. typical domestic location adjacent or below a kitchen window at the rear of the property or to the rear or adjacent to a non-domestic property. For domestic flats, installation of a heat pump system would require necessary permission from the landlord, with the installation of external heat pump units serving upper storeys potentially located at ground floor level (adjacent to bin store, car park, cycle shelter, etc.) for ease of installation and health & safety considerations.

In terms of the approach to the impact upon the electrical supply and national grid, the assumption was made that existing power supplies in domestic properties comprised of single-phase and assumed to be adequate for heat loads up to this threshold (16 kW). Through discussions with manufacturers, 16 kW appears to be the upper limit of the typical domestic range of heat pumps.

Beyond 16 kW, it was assumed that a three-phase power supply would be required. Whilst the heat pump installation costs are included in the tools, the cost of upgrading the power supply from single to three-phase will be specific to each application. Therefore, the costs of any necessary electrical work are excluded from the assessment. However, the tool does identify the requirement should NI wish to consider these costs further in the future. For non-domestic buildings, an existing three-phase power supply was assumed which would be adequate for a heating load up to the threshold of this study (45 kW).

In terms of electricity supply, the tool excludes costs related to grid and electrical reinforcements, which will be specific and bespoke to each application. The Delta study findings suggest that reducing peak demands will be significant in keeping costs to an absolute minimum and therefore would be a key driver for ensuring insulation is fitted as a minimum, however, this could also drive greater uptake of hybrid heat pump solutions and storage solutions. More research in NI is required to investigate network impacts.

6. NI Building Stock Data

The UK Housing Fact File (2013) provides important data about energy use in homes in the UK since 1970. As well as describing the current situation, it also shows changes over the last 40 years. It is intended for policymakers, researchers, and interested members of the public.

Much of the data reported comes from the English Housing Survey (EHS) based on samples. 'Sampling bias' exists as with all samples where the characteristics of a sample do not exactly match the characteristics of the whole, however due to the large sample size, this should be relatively small.

There is also a chance of inaccuracy from characteristics of dwellings that are difficult to record. For example, where difficulties accessing a loft or the inside of a cavity wall mean it is hard or impossible to assess insulation thickness, or when it is not obvious whether an installed boiler is an efficient condensing boiler or a less efficient non-condensing boiler.

Some of the data included in the Fact File is based upon modelling, which introduces some further bias potential.

Research was undertaken by Arup[30] (October 2021) to generate an evidence base to inform the development of a new Energy Strategy for Northern Ireland. The research involved the modelling of future energy demand based on NI building stock data and applicable policy levers.

A summary of the findings from the report on housing stock are reproduced below:

- The NI residential building stock comprises a variety of dwelling types: bungalows [21%], terraced houses [28%], semi-detached houses [23%], detached houses [21%] which are present in comparable proportions, except a minority (7%) of flats/apartments.
- Northern Irish residents tend to own their houses (NIHE and National Statistics, 2016), with 70% of dwellings being owner-occupied, (42% owned outright) and 28% owned with a mortgage. Approximately 13% of all dwellings are privately rented, and 12% are owned by the NIHE.
- It was found that approximately 1,900 buildings are educational buildings (nurseries, primary and secondary schools), 1,500 buildings represent the health sector (hospitals, clinics, surgeries, care homes), 1,300 buildings are other government-owned buildings (libraries, law and order establishments, defence hereditaments and coast guard, together with miscellaneous public service properties) and the remaining are Small Medium Enterprises (SMEs) and large enterprises'. This is based on the Land & Property Services (LPS) valuation list provided by the Department of Finance (2018).

There are differences between the different nation's building stock, and findings from studies undertaken based on data from the English, Welsh & Republic of Ireland residential building stock may not be directly relatable to NI:

- The NI mean domestic energy use of 17.6 MWh per year per dwelling has been estimated as the highest of the UK nations and ROI. '*The higher energy use per dwelling may be partly explained by the fact that NI has a relatively large average dwelling size and relatively high average number of persons per occupied dwelling.'*
- *The housing stock estimates (BRE Trust, 2020 reproduced by Arup, 2021) shows that NI has the highest average SAP rating for 2016 data compared to other UK nations.*
- *The NI mean non-domestic energy use of 129 MWh per year per building has been estimated as the lowest in the UK nations and ROI.*

A much greater proportion of the residential housing stock in NI (27.7%) is newer (built post 1990) than for homes in England (16.8%), Scotland (18.4%) and Wales (17.5%). Very simply, this could mean that levels of insulation and general thermal performance of the fabric of the residential building stock is likely to be better than for homes in Great Britain (GB) but worse than for homes in the ROI (41%). If this is the case, the proportion of homes suitable for heat pump retrofits is likely to be higher in NI than for the rest of GB but lower than in the ROI. This assumption is demonstrated by the number of filled cavity walls in NI compared with homes in GB (although it should be noted that the quality of cavity wall insulation works significantly impact upon the value obtained in terms of thermal performance from such works).

[30] Research into the Future of Energy Efficiency Policy in Northern Ireland | Department for the Economy

Figure 3 shows a selection of variations in data between nations in respect of their respective housing stock. The table indicates that the NI data was sourced from the 2016 NI Housing Condition Survey (HCS)[31] . Base data from HCS 2016 surveys and the LPS Valuation List were unavailable for this study.

Figure 3: Extract (Table 3) from 2016 NI Housing Condition Survey (HCS)

Table 3: Key information comparing UK nations' (BRE Trust, 2020) and RoI's housing stock (CSO, 2016), (SEAI, 2018),. England, Wales, and Scotland data is for 2017. NI data is 2016. RoI data is 2016 except proportion of dwellings built (2011 census). N/A means not available.

	England	NI	RoI	Scotland	Wales
Mean average dwelling size (m^2)	94	105	119	98	102
Mean average number of persons per occupied dwelling	2.43	2.49	2.75	2.20	2.33
Proportion of dwellings built post-1990 (%)	16.8	27.7	41.0	18.4	17.5
Dwellings with cavity walls[4]; proportion that are insulated (%)	68	90	N/A	75	68
Dwellings with solid walls[4]; proportion with insulation (%)	10	9	N/A	18	19

[4] Note that NI figures differ from information published by NIHE on number of insulated cavity walls due to different approaches to categorisation of walls (BRE Trust, 2020, p. 21).

NI Energy Performance Certificate (EPC) and Geographic Information Systems (GIS) data has been utilised in the development of this policy tool.

Energy Performance Certificates are lodged centrally within the UK, controlled via relevant Government Departments and accessed by NI Department of Finance (DoF). For this study two datasets were accessed relating to domestic EPC data and non-domestic EPC data.

The non-domestic EPC data set included a list of 14,735 non-domestic buildings lodged from May 2009 to March 2020 in Northern Ireland (approximately 20% of the total non-domestic building stock of 75,080 based on GIS data 2022). Unfortunately Display Energy Certificate data (for non-domestic buildings) was unable to be accessed. For non-domestic buildings, the dataset provided information on the type of building, size, current heating fuel and type but not age of buildings.

The domestic EPC data included a list of 570,420 domestic buildings lodged from June 2008 to November 2021 in Northern Ireland. Details of dwellings included property type (house, flat, bungalow, maisonette, park home), dwelling types (e.g. Detached, Semi-Detached, Mid-Terrace, End-Terrace, Enclosed End-Terrace, Enclosed Mid-Terrace), Dwelling floor area as well as Construction age, fuel and heating type.

The EPC data does not cover all housing and non-domestic building stock in NI. In particular, buildings that have been constructed before 2008 and have not been sold or let / rented would not require an EPC. In addition, some buildings may have had multiple EPCs produced during the period covered by the dataset, and these require removal to avoid double counting.

A report produced by Energy Systems Catapult (ESC) for NESTA in Scotland (August 2021)[32], sets out a methodology for modelling building types utilising the Energy Performance Certificate dataset for Scotland, including an approach to the grouping of buildings within age bands, a selection of the most prevalent archetypes and which energy efficiency measures should be modelled.

The tool utilised for modelling for the project is ESC's Home Energy Dynamics tool[33]. A relevant database for Northern Ireland is also available.[34]

This NESTA in Scotland report (August 2021) produced by ESC sets out a methodology for analysing Scotland's building stock to enable understanding of "*which dwellings in Scotland are most and least well suited to the transition to ground and air source heat pumps. The report contains a methodology for analysing Scotland's*

[31] NI Housing Condition Survey (HCS) 2016
[32] 'How to Heat Scotland's Homes: An analysis of the suitability of property types in Scotland for ground and air source heat pumps,'
[33] ESC's Home Energy Dynamics Tool
[34] Building Supply Chain for Mass Refurbishment of Houses, Energy Technologies Institute

housing stock with the objective of identifying the barriers to installing low carbon heating technologies and the steps required to overcome them'.

For this study, the method employed for Nesta was utilised. To remove the duplicates, the four address fields within the domestic EPC data ('ADDRESS1', 'ADDRESS2', 'POST_TOWN', 'Postcode') were concentrated to create a unique field for each entry that identified any duplication in the database. Hence, 96,268 duplicate EPCs were removed, and the remaining 474,152 EPCs were used in this assessment. For the duplicated EPCs, the most recent EPC was retained in the dataset, and the older data was removed. It should be noted that some level of duplication may still exist in the data since the method relies on an exact match which could miss duplication if the input data was slightly different across EPCs. The results are shown in Table 5 and Table 6 and include the percentages of each building type against the time that they were built.

The non-domestic dataset did not include the four address fields used to identify duplicated data in the domestic EPC data. The only alternative data field that could be used to remove the repeated entries was the BUILDING_REFERENCE_NUMBER which did not include any duplicated numbers. It should be noted that some level of duplication may remain within the data.

Table 5: The Proportion of NI Housing Stock Built, Sold or Rented Since 2008 by EPC Rating (%)

	A	B	C	D	E	F	G	Sum
Mid-Terrace	0.1%	3.7%	27.3%	43.1%	18.2%	6.5%	1.2%	100%
Flat	0.1%	19.9%	51.9%	20.6%	5.1%	1.8%	0.5%	100%
Semi-Detached	0.2%	20.6%	19.3%	33.7%	18.3%	7.0%	0.9%	100%
Detached	0.4%	21.7%	19.1%	29.3%	16.9%	9.7%	2.8%	100%
End-Terrace	0.1%	5.9%	19.5%	46.8%	19.6%	7.0%	1.2%	100%
Bungalow	0.1%	3.3%	10.2%	43.2%	29.5%	11.5%	2.2%	100%
Unknown	0.0%	10.4%	16.6%	31.8%	26.4%	12.0%	2.9%	100%

Table 6: The Number of NI Non-Domestic Stock Built, Sold or Rented Since 2008 by EPC Rating

Property Type	Number of EPCs	A+	A	B	C	D	E	F	G
A1/A2 Retail and Financial/Professional services	7147	0	36	563	2374	1855	1048	597	674
B1 Offices and Workshop businesses	2326	0	24	176	484	486	368	250	538
A3/A4/A5 Restaurant and Cafes/Drinking Establishments and Hot Food takeaways	1182	0	1	44	277	402	264	119	75
B8 Storage or Distribution	762	0	4	34	279	200	107	46	92
Retail	677	0	2	56	254	203	75	39	48
Office	438	0	2	35	105	106	61	39	90
B2 to B7 General Industrial and Special Industrial Groups	409	1	0	19	127	95	60	31	76
D1 Non-residential Institutions – Education	247	0	18	152	31	14	12	7	13
D2 General Assembly and Leisure plus Night Clubs and Theatres	220	0	3	54	58	43	23	17	22
D1 Non-residential Institutions - Community/Day Centre	213	0	8	78	43	33	19	15	17
C2 Residential Institutions - Hospitals and Care Homes	187	0	5	67	59	39	13	4	0
Warehouse and storage	166	0	2	6	27	35	41	26	29
C1 Hotels	132	0	2	21	37	36	26	10	0
D1 Non-residential Institutions - Primary Health Care Building	108	0	1	13	19	31	22	16	6
Restaurant/public house	87	0	0	3	18	25	19	15	7
Retail warehouses	86	0	0	28	40	10	4	1	3

The EPC data was cross-referenced with a more complete dataset to understand better how representative the EPC data is. To do this exercise for NI the OSNI GIS database was utilised, which comprises a full list of buildings in NI and enables identification of spatial location.

Some of the known limitations of the EPC data include:

- Some of the EPC data is old and now out of date (some EPCs over 10 yrs old) and there are likely to have been improvements in some instances to homes and non-domestic buildings.
- The construction age band is only provided for dwellings.
- The non-domestic EPC dataset does not provide information around fabric and building elements to allow for identifying consequential improvements beyond the building age band default specifications.

The GIS database provided by NI DfE includes the OSNI Central Postcode Directory, the OSNI Fusion, the OSNI Pointer and the OSNI Property Data. Among this, the most useful database for this study was the OSNI Pointer database which provided a full building stock database that included the building types with their unique UPRN numbers as well as building type and location for all the non-domestic building stock in NI.

Based on GIS data received in January 2022, there are 75,080 non-domestic buildings and approximately 820,000 domestic buildings in NI. The numbers produced by Arup in the Delta report indicate that numbers are relatively accurate e.g. Arup cite 1,900 educational buildings, with 1,841 identified in the table below: Arup cite 1,500 health related buildings, with 1,481 identified in the table below.

All non-domestic buildings with their GIS Primary Use Class are identified in Table 7.

Table 7: Breakdown of Non-Domestic Buildings in NI

GIS Primary Class	Total Number of Properties	Proportion (%)
Shops, Showrooms, Supermarkets etc	19,812	26.4%
Offices (Includes Banks and Post Offices)	16,677	22.2%
Warehouses, Stores, Workshops, (Non-IND) Garages	13,967	18.6%
Manufactories	4,250	5.7%
Churches, Church Halls etc	3,009	4.0%
Non-Sporting Rec Facility	2,337	3.1%
Car Parks	2,131	2.8%
Schools etc	1,841	2.5%
Hospitals, Clinics, Surgeries, Homes	1,481	2.0%
Commercial Unclassified	1,372	1.8%
Licensed Premises	1,209	1.6%
Miscellaneous Public Service Properties	1,143	1.5%
Telecommunications	1,127	1.5%
Sporting Recreational	1,101	1.5%
Advertising Stations and Signs	989	1.3%
Unlicensed Accommodation	975	1.3%
Other[35]	1,659	2.2%
Total	**75,080**	**100%**

A breakdown of proportions of different dwelling types in NI from the GIS data is presented in the Table 8. The proportions for Semi and Terrace are similar to the figures provided in Section 6. Whilst inclusion of the bungalow type within the GIS detached column partly explains this discrepancy, this doesn't account for the variation in proportion of apartments. One possibility is that where houses have been divided into flats, these are still recorded as houses in the GIS data.

Table 8: The Proportion of Building Types from the Available GIS Data (%)

The total number of domestic buildings based on the GIS data is approximately 820,000 properties.

	Arup 2021 (Refer to Section 6)	2022 GIS Data
Flat	7%	11%
Semi	23%	26%
Detached	21%	36%
Terrace	28%	28%

[35] Building classes with less than 1% proportion are combined with other category.

7. Building Archetypes

The report produced by Delta Energy & Environment Ltd, (December 2018) on behalf of the Department for Business, Energy & Industrial Strategy (BEIS)[36] utilised housing archetypes for the purposes of modelling.

The BEIS study covers four house types (detached, semi-detached, mid-terrace and end terrace) and excludes flats. The Heat Scotland's Homes project categorises the buildings based on their age and building type (mid-terrace, end-terrace, semi-detached, detached and flats), similar to the approach adopted in this study. The main differences in this study are the addition of the bungalow house type and combining the semi-detached category with the end terrace archetype.

7.1 Domestic Archetypes

Based on the EPC and GIS data analysis, five building types are considered within our modelling. Each building type is modelled using average floor area based on EPC data analysis (Table 9).

Table 9: The Domestic Archetypes Selected for Building Energy Modelling Exercise

	Detached	Semi-detached	Mid-Terrace	Flat (middle floor)	Bungalow
Average Floor Area (m^2)	180.3	97.5	84.8	59.9	104.9
Height (m) (floor to ceiling)	2.4	2.4	2.4	2.4	2.4

The average floor area (104.8 m^2) for the five dwelling archetypes corresponds closely with the Arup quoted mean average NI dwelling size of 105 m^2.

Following analysis of the EPC data, an assumed floor to ceiling height of 2.4 m was discussed and agreed upon with NI and utilised in modelling. The floor height was applied within the thermal model and used to generate heat loss and heating energy data.

7.2 Non-Domestic Archetypes

Based on the GIS data analysis, non-domestic archetypes for the building 'energy modelling' exercise were selected including retail shop, office, school and restaurant/cafe. Based on the nature of the activities undertaken in the buildings and their likely energy profiles, these archetypes were selected as they would cover the majority of cases and could represent approximately 55% of the non-domestic building stock in NI. The remaining other building archetypes generally represent lower percentages of the non-domestic building stock in NI.

Table 10: The Non-Domestic Archetypes Selected for Building Energy Modelling Exercise

Non-Domestic Archetype	GIS Primary Class	Example of Buildings for Heat Pump Assessment Tool
Retail Shop	Shops, Showrooms, Supermarkets etc Filling Stations	Small shops (town house buildings)
Office	Offices (Includes Banks and Post Offices) Hospitals, Clinics, Surgeries, Homes Law and Order Establishments Libraries etc	Small commercial offices Small surgeries Clinics Police stations Libraries
School	Schools etc	Primary schools Nurseries
Restaurant / Cafe	Licensed Premises	Café (town house buildings) Small restaurants (town house buildings)

[36] Technical feasibility of electric heating in rural off-gas grid dwellings'

The following categories of non-domestic buildings are excluded from consideration in the policy tool analysis:

- Warehouses, Stores, Workshops, (Non-IND) Garages and Manufactories – only the office area might be suitable for a Heat Pump retrofit (up to 45 kW) but these are likely to already be electrically heated/cooled. If the warehouse itself requires conditioning, this will likely exceed the 45 kW threshold.
- Churches, Church Halls – church buildings are often temporarily heated spaces and, because heating is required to be rapid and targeted, 'wet' heating systems are unlikely to be utilized. Only church halls are potentially suitable.
- Sporting Recreational – sports facilities are often unconditioned spaces and, where this is not the case, 'wet' heating systems are unlikely to be utilised for heating.
- Non-sporting Recreational Facility – these include cinema and theatres. Buildings of this class are likely to be mechanically heated/cooled via ceiling cassette-based systems or Air Handling Units (AHU) utilizing electric batteries.
- Unlicensed Accommodation relates to smaller businesses such as bed and breakfasts, hostels, holiday homes, etc., and, given that they are likely to be very similar to large dwellings, the analysis undertaken of dwellings is pertinent.

The UK Government's definition of Microgeneration[37] applies to a mix of heat and power generating technologies with a thermal output below 45 kW_t or an electrical output of 50 kW_e. It covers electrical generation from wind, solar photovoltaics (PV) and hydro, heat generation from biomass, solar thermal and heat pumps as well as micro CHP which produces heat and power from renewable or fossil fuels. It is not just another term for small scale renewables but comprises a portfolio of low carbon technologies.

The Microgeneration Certification Scheme (MCS) 45 kW thermal output limit forms the boundary of this study which means that the policy tool needs to consider small non-domestic buildings where the total peak space heating and hot water demand can be satisfied via technologies of 45 kW installed capacity or less. To identify such buildings likely to be within the threshold, the maximum building area for each archetype was estimated using a range of sources including the benchmark, metered data and modelling results.

Table 11: The 45 kW Peak Heat Demand Threshold and Building Area

	Maximum Building Area for 45 kW p Peak Demand (m²)			
	Office	**Retail Shop**	**Restaurant / Café**	**School**
Benchmark Note 1	479	291	69	623
Metered Data Note 2	314 – 448	Not available	Not available	310 - 627
Modelling Note 3	451	Not available	Not available	756

Note 1: Based on CIBSE TM46
Note 2: Based on the NI public building datasets supplied by NI DfE
Note 3: Based on preliminary thermal modelling

Table 12 shows the number of non-domestic EPCs (excluding those for buildings where electricity is the main heating fuel) with a floor area less than that estimated based on 45 kW peak demand limit. The EPC dataset included building floor areas and heating fuel type. This data together with a combination of modelling data and benchmarking was used to identify a peak heating demand (kW/m^2) to identify the maximum floor area for each building type (that would require <45 kW).

It is acknowledged that this approach is likely to under-estimate the number of buildings where heat pump retrofits are suitable as, post installation insulation measures, means the heat demand for more buildings will fall below the threshold.

[37] DTI Microgeneration Strategy 2006: [ARCHIVED CONTENT]

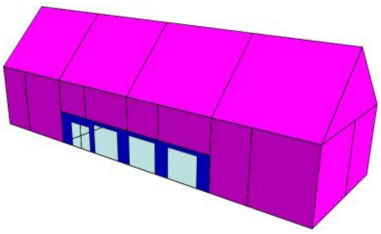
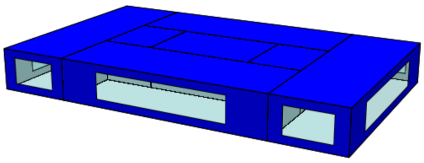
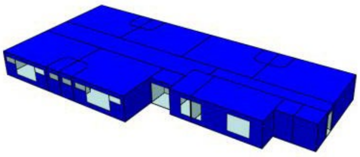
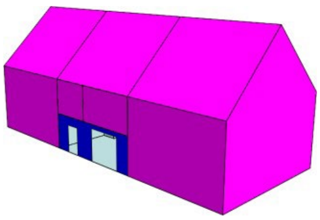
Table 12: Breakdown of Non-Domestic Archetypes in the EPC Dataset Within a 45 kW Peak Heat Demand

Archetypes	Number of EPCs excluding buildings with electricity as main heating fuel	Number of EPCs excluding buildings with electricity as main heating fuel and floor area less than the threshold based on 45kW limit	Proportion to the total number of EPCs within the same archetype	Floor area estimated based on 45kW limit
Retail	2,518	1,589	63%	291
Offices	1,852	1,231	66%	479
Health Care	91	73	80%	479
Food and drinking establishments	770	60	8%	69
Education	270	203	75%	756
Totals	**5,501**	**3,156**	**57%**	**n/a**

Table 12 shows a low percentage of ‘food and drink’ establishments covered under the proposed research. Many modern stand-alone and/or larger restaurants will utilise electrically driven air-based systems for heating and cooling. The assumption is that restaurants likely to fall within the remit of this research (wet heating systems) are smaller, high-street based cafes/ restaurants based on the ground floor of large domestic type properties.

Based on the size and building type characteristics of NI stock, the geometries for the archetypes utilised in this study are shown in Table 13.

Table 13: Non-Domestic Archetypes Adopted in this Study

Non-domestic Archetype	Model geometry (geometry in blue) Note 1	Description
Retail Shop		Total floor area to be modelled (m^2): 126
Office Note 2		Total floor area to be modelled (m^2): 540
Education Note 2		Total floor area to be modelled (m^2): 714
Restaurant / café		Total floor area to be modelled (m^2): 63

Note 1: The areas shown in pink will be assumed to be with adiabatic conditions i.e., there will be no heat transfer in either direction across adjacencies i.e. shared walls, floors, ceilings, etc.

Note 2: The current versions of the Standard Assessment Procedure (SAP) for dwellings and Simplified Building Energy Model (SBEM) are utilised in NI and in this study. In SBEM, where there is an unheated, unoccupied roof space (i.e. between a pitched roof and a flat ceiling) above an activity area, this void is considered as part of the construction when calculating the U-value between the occupied activity area and the outside (i.e. the top floor ceiling is defined as a ‘roof’ and the combined thermal performance of the whole construction includes the ceiling construction, the void, and the roof construction).

8. Heating and Hot Water Systems

8.1 Best Practice Guide for Air Source Heat Pump Retrofit - Superhomes 2.0

The purpose of the Superhomes 2.0 (SH2.0) project[38] in ROI, was to research optimisation of real-world residential energy retrofit installations that included Air Source Heat Pumps.

The report presents the guidelines that refer to the 20 homes monitored in the project. The key steps in the process of retrofitting dwellings with a heat pump were identified including the correct sizing of an ASHP (considering building load, the effect of ice build-up on the evaporator and the use of variable speed compressors) and design considerations for radiators (showing the effects of installation and commissioning set-up on system performance).

The report refers to EN 12831 as a method for calculating the design heat load for a building. Heat loss calculations per individual room should be used in the design of the heat emission system. This process calculates the building fabric and ventilation heat losses. In addition, the application of a re-heat factor (RHF) is recommended by EN12831.

The project findings show:

- Energy consumption for defrost cycles should be within 1% of total energy consumed for a well-designed and commissioned system.
- Continuous low flow of the Heat Pump is preferable, with no interruption from Thermostatic Radiator Valves (TRVs).
- Retrofitted heating systems generally retain some or all of the original heating distribution system.
- The hot water demand is excluded from the sizing exercise as it assumed that the heat pump can be diverted to the production of hot water as and when it is required.

The report provides some interesting findings, but there are reasons for caution in applying all of the findings to the policy tool. The report is a detailed on-site investigation of a limited number of dwellings in ROI, with real time data capture. This study is unable to delve into this much detail, having to make assumptions that will apply across NI domestic building stock, as well as non-domestic buildings. Dwelling Energy Assessment Procedure (DEAP) is employed for the modelling within the ROI report, whereas full Standard Assessment Procedure (SAP) is used for this study (refer to section 2.8 for a comparison of DEAP and SAP). The ROI research was also based on expensive deep retrofit to nearly zero carbon and there are therefore different objectives to those of NI Heat Pump Tool study.

8.1.1 Modelling Approach Adopted Within the Policy Tool

Energy consumption associated with periodic winter defrost cycles of the external heat pump unit have been assumed to be included within the SCOP values.

The policy tool is unable to make any assessment of the existing heating system site set up and heating controls, however the use of continuous low flow of the heat pump with no interruption from TRVs is assumed achievable.

Where the existing building has a wet heating system, the retrofitted heating systems assumes that the original heating pipework distribution system will be retained.

When sizing the ASHPs for the policy tool, consideration of domestic hot water generation has been excluded from the peak heating load as it is assumed, as for ROI, that the heat pump is temporarily diverted to hot water production as and when it is required (also see 8.2 below).

[38] Superhomes 2.0, Best Practice Guide for ASHP Retrofit, Limerick Institute of Technology, March 2019 (PDF) Superhomes 2.0 Best Practice Guide for ASHP Retrofit

8.2 Written Evidence Submitted by Heating and Hot Water Industry Council

When assessing energy efficiency measures in UK homes the Heating and Hot Water Industry Council (HHIC)[39] highlighted that many home upgrades include a cylinder disposal, which makes things more complicated if any future upgrade requires this cylinder to be installed back to the building. A similar situation exists for radiators, as they are quite old in the majority of the building stock and their replacement adds cost and time for the whole system upgrade.

In relation to room temperature control the minutes state that in practice, the ASHP performs best when TRVs do not introduce interruptions to the heat emission system and so homeowners were advised to set the TRVs to their maximum setting so that they would not close down and prevent a flow of water, except in the case of bedrooms where it is necessary to maintain a lower temperature than in living areas.'

All of the systems in the SH2.0 project are controlled to prioritise the production of domestic hot water (DHW) and so the heat pump is never tasked with simultaneously heating DHW and heating the building. In all cases, the output required for space heating exceeds that required for DHW and so no further DHW factor was added to the design capacity of the heat pump as is suggested in EN12831. This is likely to also be applicable to non-domestic building archetypes selected for the policy tool.

Finally, the report refers to hybrid systems however, the extent of the opportunity for hybrid systems is unclear. Whilst hybrid systems may be able to deliver the heat and domestic hot water at the coldest periods, it is unclear if this can be done without a major change of the existing plant.

Consultation with manufacturers suggests that some may only offer packages of their own compatible boilers, heat pumps and hot water storage cylinders, then interface this with their own controls package. There appear to be some control systems on the market that could enable the use of existing boilers with new heat pumps, however it is unlikely that the existing hot water tank and valve arrangement is suitable (without modifications) to suit a new system.

8.2.1 Modelling approach adopted within Policy Tool

The modelling tool assumes that the installation of a new heat pump system would require and includes for the replacement or provision of a new domestic hot water heating cylinder compatible with the selected heat pump.

By including a new domestic hot water storage cylinder this ensures that domestic hot water is available when required with the heat pump set to divert to re-charging the storage cylinder when necessary (avoiding simultaneous heating and domestic hot water production). The new domestic hot water storage cylinder would also be correctly sized to match the operating temperature of the new heat pump system.

8.3 Domestic Heat Distribution Systems: Evidence Gathering, Final Report

Articles posted by the Energy Saving Trust[40] (EST) on heat pumps in February 2021 and June 2021 respectively, discussed some of the perceptions held in relation to heat pumps. One of these was that "*heat pumps only work with underfloor heating*". EST's published response was that *"heat pumps are compatible with underfloor heating and radiators – although it may be more efficient if connected to an underfloor heating system. Larger radiators, which give out heat at lower temperatures over longer periods of time, can help to maximise the benefits of heat pumps. It's also worth ensuring that you have suitable insulation in your home, as this will help to minimise heat loss."*

A report produced by BEIS[41] focused on the state of heat distribution systems in the UK housing stock and the measures that could be taken to improve these systems. Three main sources of evidence gathering that were used for this study were the literature review, stakeholder engagement and primary data collection on dwellings.

A total of 515 domestic properties were surveyed in the UK. This involved a certified Energy Performance Certificate assessor completing a survey of each property's heat distribution system while carrying out their Reduced data Standard Assessment Procedure (RdSAP) assessments to produce an Energy Performance Certificate (EPC).

[39] Written evidence submitted by the Heating and Hot Water Industry Council (HHIC)
[40] Setting the record straight on heat pumps - Energy Saving Trust
[41] BEIS Heat Distribution Systems Evidence Gathering - Final Report_Draft_ISSUED

This allows for a calculation of the "over-sizing factor" of a dwelling's heat distribution system, defined by the rated thermal output of the radiators in a dwelling divided by the peak steady state heat demand (kW) for the same dwelling. From UK housing stock data, a full stock of dwellings in the UK with wet central heating systems was created, and information gathered about heat distribution systems from the primary surveys mapped against this list.

One of the findings of the report was that there is significant uncertainty in the calculation of the SAP heat loss coefficient, and studies have suggested that the heat loss coefficient of dwellings is 45% larger than that calculated by SAP when measured in a co-heating test. The study also supported the suggestion that radiator capacities in existing homes are 'over-sized in many buildings (20% oversized after the mid-2000s, and approximately 35-40% oversized before the mid 2000's).

The report gives a quantitative description of the changes that may be needed to convert to a low temperature heat source (thermal output of radiator, radiator oversizing factor).

The study confirmed that *"10% of dwellings in the UK are already suitable, on a peak winter day, for heat pumps with a 55°C flow temperature with no changes to their heat distribution systems; only 1% are suitable for a heat pump with a flow temperature of 45°C. However, when considering reductions in radiator performance over time or additional heat demand above what is calculated by SAP, these figures are significantly reduced".* When assuming the average temperature for the coldest winter month (not the peak day) the study states that *"The results suggest that 53% of dwellings can be heated with a 55°C flow temperature with no changes in their heat emitters or flow rates for most of the heating season […] The results suggest that there is an opportunity for hybrid heat pumps, or heat pumps with additional heat sources such as electric fan heaters, to be used with no changes to heat distribution systems, with the heat pump providing the vast majority of the annual heating demand (kWh), across a relatively large portion of the housing stock."*

The report findings cannot be assumed to be entirely representative of NI. Whilst some of the UK data used for the analysis related to properties based on the NI Housing Condition Survey (2016), the relative numbers from each country are unknown. Where the report comments upon the under-estimations of SAP, it should be noted that NI weather files were not used for this calculation. Also, small non-domestic buildings are not included in this study.

The report does not include much detail about pipe sizes and replacement, but the costings within the report assume that if larger radiators were required, pipework would also be replaced. Replacement pipework is potentially much more of an issue from the perspective of the cost of internal disruption and repair (e.g. pipes in screed with flooring over the top). If pumps are correctly sized for the existing heating system, they should not pose a barrier to the retrofit of heat pumps.

The figures in this report (showing 10% and 1% of dwellings being suitable at flow temps of 55^{o}C & 45^{o}C) suggest that the application of low temperature heat pumps will not be straightforward , with other measures often required e.g. energy improvements to reduce heat load, consideration for either high temperature heat pumps or hybrid heat pumps, upgrading of radiators and pipework, or the need for a secondary heat source for peak winter days, all adding additional capital and operational costs.

8.3.1 Approach Adopted Within the Policy Tool

The policy tool scenarios are modelled on flow rates of 55^{o}C (to align with 2022 Part L proposals in England and Wales) and sizing of heat pump plant based on meeting winter peak temperatures. This will work well within any existing underfloor heating systems however this essentially means that almost all buildings with other wet heating systems will require some retrofit of radiators and costs have been included within the policy assessment tools.

8.4 Heat Output and Performance of Existing Heat Emitters

Traditional heating systems operate with flow temperatures up to 70-80°C with the existing output of heat emitters (typically radiators) sized at these temperatures. For systems operating at other temperatures, the output of a radiator will vary depending on the difference between the mean radiator temperature and the room condition (ΔT). Table 14 summarises the radiator operation factor from BS EN 442 with a number of key temperature conditions highlighted used in the examples below:

- **Example 1:** The operating factor is normalised for a traditional heating system operating with a 75°C/65°C flow / return temperature and a room temperature of 20°C, with leads to a ΔT of 50°C. This is highlighted by the green row and has an operating factor of 1.0.
- **Example 2:** At the common operating conditions for heat pumps of 55°C/45°C flow / return temperature and a room temperature of 20°C, with leads to a ΔT of 30°C. This is highlighted by the yellow row and has an operating factor of 0.515 => 51.5% of the output of a traditional heating system in example 1.
- **Example 3:** Increasing the operating conditions into the range of "high temperature" heat pumps of 65°C/55°C flow / return temperature and a room temperature of 20°C, with leads to a ΔT of 40°C. This is highlighted by the blue row and has an operating factor of 0.748 => 74.8% of the output of a traditional heating system in example 1.

As can be seen in the above examples the heat output of existing radiators will be significantly affected and reduced as the operating conditions of an existing heating system are reduced from traditional temperatures.

Table 14: Radiator Performance at Different Temperatures

Flow Temperature, °C	Return Temperature, °C	Mean Radiator Temperature, °C	Room Temperature, °C	Mean Radiator to Room Difference ΔT, °C	Operating Factor
30	20	25	20	5	0.050
35	25	30	20	10	0.123
40	30	35	20	15	0.209
45	35	40	20	20	0.304
50	40	45	20	25	0.406
55	45	50	20	30	0.515
60	50	55	20	35	0.629
65	55	60	20	40	0.748
70	60	65	20	45	0.872
75	65	70	20	50	1.000
80	70	75	20	55	1.132
85	75	80	20	60	1.267
90	80	85	20	65	1.406
95	85	90	20	70	1.549
100	90	95	20	75	1.694

8.4.1.1 Effect on Existing Radiators

In summary, even with a "high temperature" heat pump operating at a flow temperature of 65°C any existing radiator will have its output significantly reduced (down to 74.8%). To ensure that the required heating load would still be delivered, the original radiator would need to have been oversized by 33.7%. In a building most existing radiators would not evenly and consistently have this level of over-sizing, therefore a site visit and detailed assessment of the existing radiators would be required.

Such a loss of performance from the existing radiators (33.7%) is likely to have a notable effect experienced by the users, i.e. the radiators will not feel as hot as previously, as the heating system will be running at a lower temperature and the building warm up time will be significantly increased. Even in such cases where the existing radiators were significantly oversized to begin with, this could lead to the situation where the users perceive the loss in radiator performance as a sign of the new heat pump system underperforming and not adequately heating the building, potentially leading to complaints regarding comfort conditions.

The loss in existing radiator performance is even more significant with a heat pump operating at a flow temperature of 55°C, (only 51.5% of original output), requiring the original radiators to have had been oversized by 94.2% which is extremely unlikely. In both scenarios the existing radiators would need to be reviewed and most likely require upgrading to ensure comfort conditions are achieved and dissatisfaction avoided.

In newer buildings constructed to higher building fabric standards there is less opportunity to reduce the heating demand of a building through adopting fabric improvement measures and as such the existing heat emitters are again likely to require upgrading or replacing.

Even within older buildings, where improvements to the building fabric can offer greater potential reductions in heat load, achieving such reductions evenly across an entire building could be challenging and uncertain. In practice, a detailed site visit would be required and an assessment undertaken of each heat emitter to verify which, if any could be retained.

8.4.1.2 Underfloor Heating Systems

Underfloor heating systems typically operate at lower flow temperatures, with high temperatures blended locally, and so may not be similarly affected as outlined above. Where this is the case, such systems can be retained when operating with heat pump systems at any standard temperature conditions. However, the extent to which underfloor systems are affected is dependent upon the layout of the underfloor pipework i.e. the size and spacing of pipes in the ground, and this would require checking for compatibility with the heat pump solution.

8.4.2 Approach Adopted Within NI Heat Pump Tool

Based on radiator performance reduction against heating flow temperature outlined above and the absence of information from a site visit, policy tools were developed on the basis of a standard heat pump operating at 55°C with the cost of replacement radiators included where applicable, i.e. to give a realistic guide to cost. In the case on buildings with underfloor heating systems these were assumed to be retained.

9. Heat Pumps

9.1 Types of Heat Pump & Heat Sources

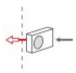
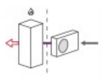
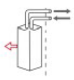
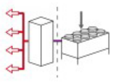
A study produced by the Greater London Authority (GLA)[42] sets out a list of the different ways in which heat pump systems can be set up in a building:

- **Individual monobloc unit** - a single block system where the heat pump has all of its components (apart from the hot water cylinder which is installed in the home) located inside a heat pump unit situated outside the home. Most homes, and potentially small business premises in the UK are ideal for a monobloc air to water heat pump. Installers do not require F Gas qualifications.
- **Split systems** - have both an outside unit, which incorporates the heat exchanger and refrigerant, and an internal unit, which sits inside the property, usually in a utility or boiler room. A split system is an option generally for more complex installations, and it can be installed up to 30 m away from the building, which gives more flexibility.
- **Hybrid split systems (with boiler)** - a system that uses a heat pump alongside another heat source. Typically, it describes fitting a heat pump alongside a fossil fuel (gas, oil or LPG) boiler. This boiler could be an existing boiler, or you could be considering installing a new boiler at the same time as the heat pump. Hybrids might be utilised where the building has a high demand for heat, or the heat pump does not provide ongoing cost savings and these reasons would inform the final system design.
- **High temperature air to water heat pumps** - designed for poorly insulated or particularly large properties, and those where, replacing existing radiators or improving the insulation in the home isn't possible. These high temperature heat pumps can heat water up to 70 or 80°C.

A news article[43] written by Tom Lowe (June 2021) to which BEIS has responded to, points to a claim about heat pumps that "**"**Many homes do not have space for them".

The GLA study[42] contains the following two figures illustrating the space impacts of different configurations of heat pump (Figure 4):

Figure 4: Extract of Space Impacts of Air Source Heat Pumps[44]

Type	Ref	Example	Additional space implications		
			DH Energy Centre	Building	Dwelling
AIR SOURCE Small-A1		Monobloc			External space required (e.g. balcony)
AIR SOURCE Small-A3		Hybrid			External space required (e.g. balcony) and in unit ~1sqm
AIR SOURCE Small-A4		Compact unit Heat Pump + MVHR			Space required in unit ~1sqm
AIR SOURCE Medium-W1		Communal air source heat pump to heat interface units (HIUs)		Additional ventilated or open-air plant room*	

The 'Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings[45] (BEIS) study identified the fraction of houses where electric heating systems are expected to be practically suitable, as shown in Table 14 within the report.

[42] Low Carbon Heat: Heat Pumps in London, Greater London Authority
[43] Major challenges in persuading homeowners to install heat pumps, government admits | News | Building
[44] Low Carbon Heat: Heat Pumps in London, Greater London Authority
[45] Technical feasibility of electric heating in rural off-gas grid dwellings

Figure 5: Extract (Table 14) Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings[46]

House Type	Fraction of houses that technology will practically fit into							
	ASHP		GSHP		Direct electric heaters		Storage heaters	
Detached	V. good	90%	Good	75%	Excellent	95%	V. good	90%
Semi-detached	Good	75%	Moderate	50%	Excellent	95%	Good	75%
Terrace	Good	75%	V. difficult	10%	Excellent	95%	Moderate	50%
Flat	Difficult	25%	Zero	0%	Excellent	95%	Moderate	50%
Reasoning	Space needed for outside unit		Space needed for laying coils / digging borehole		Requirement for new wiring (main electricity loop) in older houses		Size is key issue – large units in each room	

Space availability is likely to be one of the key determinants of the choice of Heat Pump type and configuration. Figure 5 above ignores existing planning requirements but considers the physical and practical space constraints of different heating applications. It can be seen from the BEIS study that air source heat pumps should be able to be accommodated in the majority of houses but there may be issues for retrofit to apartments due to the need for heat rejection units. In NI, the GPDO only refers to dwelling houses. The exclusion of apartments would mean the need for a planning application for each case. Consideration would need to be given to how the unit would be fixed to the building and the heat and noise impact on surrounding apartments.

As well as different configurations, there are also different heat sources that can be utilised by heat pumps. The Microgeneration Certification Scheme (MCS) Domestic Heat Pumps – A Best Practice Guide[47] identifies the following types of heat pump (Table 15):

Table 15: Heat Pump Types Referred within the Heat Pump Guide

Heat Pump Types
Air Source: Air-to-Water (or “A-W”)
Air Source: Air-to-Air (“A-A”)
Ground Source: Closed Loop: Water to water: (W-W)
Ground Source: Open Loop via subterranean aquifer (W-W)
Water Source: Open Loop via surface water (W-W)

Air Source, Air to Water Heat Pumps: These heat pumps take heat from the outside air and transfer it to a water-based system. The heat created can be used for space heating or as a hot water supply for a building. An air to water heat pump is among the most efficient on the market. This type of heat pump works best in moderate climates.

Air Source, Air to Air Heat Pumps: These heat pumps fall under the category of air source heat pumps, and by using renewable energy and hybrid solutions, can provide both heating and cooling for a building. This type of Heat Pump is one of the most affordable heat pumps on the market.

Ground Source Closed Loop Water to Water Heat Pumps: These heat pumps use a system of high-quality polyethylene pipes which circulate thermal transfer fluid through the ground or through a body of surface water, absorbing heat (heating) or rejecting heat (cooling). The closed loop design is determined by the geology of the ground and the energy demands of the building. Geothermal models need to be developed to demonstrate efficiency and sustainability. There are several alternative closed loop geothermal energy systems as outlined below:

- **Vertical**: This system is composed of pipes that run vertically in the ground. This type of design is very versatile and works particularly well in built up areas where horizontal schemes are not practical.

[46] Technical feasibility of electric heating in rural off-gas grid dwellings
[47] Table 3: Heat-Pump-Guide.pdf

Performance enhancement of closed loop systems can be achieved with Borehole Thermal Energy Storage and artificial recharge.

- **Horizontal**: Pipes run horizontally in the ground along a trench or through horizontally drilled boreholes. Horizontal loop is often chosen when there is no limitation on land or space for installing the system.

  Schools with playing fields, rural commercial buildings, residential property and agricultural buildings are where this type of ground source design is most likely to be recommended.

- **Surface Water**: This system exchanges energy with the body of water in which the loop or heat exchanger plates are placed. Systems are suitable in coastal developments, inland rivers and lakes where the temperature differentials are adequate to deliver the energy requirements of the building.

  In the right circumstances these systems offer very cost-effective energy solutions.

- **Structural**: This system is one which uses the foundation piles or building structure to hold the closed loop geothermal heat exchange system. The system may be cast on site or prefabricated depending on the structure and design of the building and the targeted energy requirements.

Ground Source Open Loop Via Subterranean Aquifer, Water to Water Heat Pumps: Groundwater is pumped from an aquifer, or alike, and carried to the heat pump, where, by means of the evaporator, transfers its heat. After that, that water is either re-injected into the ground or discharged at the surface. Thus, the heat source is the same as the fluid that runs through the circuit, which must be constantly replaced since it's not re-circulated.

Water Source Open Loop Via Surface Water, Water to Water Heat Pumps: This system utilises a surface body of water as the heat exchange fluid travels through the heat pump. After it has dispersed though the whole system, the water returns to a recharge well or a surface discharge.

There are significant differences between air, water and ground source heat pumps, the most obvious being the need for the physical space and land characteristics to support the latter two. The permitted development for the latter two is also different as are the capital costs. However, usually, the seasonal efficiencies of the latter two types are significantly better than for an Air Source Heat Pump which is discussed below.

9.1.1 Approach to Type of Heat Pump Adopted in Policy Tool

Due to its (almost) universal application (it doesn't rely on the presence of a body of water, ground conditions or large physical spaces) a single Air Source Air to Water Heat Pump providing space heating and domestic hot water has been chosen as the preferred source of heat pump in the development of the NI Heat Pump Tool. Ground Source Heat Pumps (GSHPs) and Water Source Heat Pumps (WSHPs) are both likely to give higher SCOPs and therefore reduced running costs and carbon dioxide (CO_2) emissions but the number of installations will be much more limited and bespoke to site, or of greater complexity and higher capital cost.

9.1.2 Consideration of Other Type of Heat Pumps

To assess the relative merits and drawbacks of high temperature and hybrid heat pumps a range of different scenarios were considered. The findings for each type of heat pump system are outlined below.

<u>High Temperature Heat Pumps</u>

The main advantage of high temperature heat pumps is that these can operate with flow temperatures above 55°C and so have less effect on the heat output of any existing heat emitters (typically existing heat emitters would be sized and operate with traditional flow temperatures of 80°C). Whilst general literature available from heat pump manufacturers can state that these operate up to 70°C and above, where technical data is available these units typically operate at 65°C. In some cases, with sufficiently high heat pump flow temperatures, any reduction in heat output[48] of the original heat emitters (typically radiators) may be limited, and retention of the existing heat emitters may be possible[49] (subject to the remaining life of the original heat emitters). Where possible this would avoid any associated costs of replacing heat emitters (less internal disruption and intrusive work throughout the property) assisting to make installation of a new heat pump heating system more attractive.

The main disadvantage of a high temperature heat pump over a standard temperature heat pump is the significant reduction in system performance. The higher the flow rate temperature the more dramatic the resulting loss of

[48] Information regarding heat output and performance of existing heat emitters can be found in Section 8.4.
[49] Subject to a site visit and detailed assessment of existing heat emitter / radiator condition / sizing against the actual operating performance data for a specific proposed high temperature heat pump.

performance, as demonstrated within Figure 7. For example, a standard heat pump operating at 55°C can have a seasonal coefficient of performance (SCOP) of 2.8 or greater. This compares to a high temperature heat pump operating at 65°C with a seasonal coefficient of performance (SCOP) of 2.0[50] or lower. Therefore, a high temperature heat pump will always result in higher operating costs and carbon dioxide emissions relative to a standard temperature heat pump system operating at 55°C or lower.

Other disadvantages include an increase in the initial capital cost of a high temperature heat pump over a standard temperature heat pump and there is a more restricted selection of heat pumps available[51] with less market competition.

To summarise, greater reductions in carbon dioxide emissions can be gained by avoiding any capital cost premium for a high temperature heat pump over a standard heat pump and any capital costs savings used towards the cost of any replacement or upgrade of existing heat emitters where necessary. In a number of cases the high temperature heat pump capital cost increase could be greater than the cost of replacing or upgrading existing heat emitters. The policy tool has been developed on the basis of air source heat pumps operating at standard temperatures.

The existing heat emitters may still require replacement/upgrading to maintain the original room heating output even when operating at flow temperatures of 65°C or above and would still require a site visit and detailed assessment to verify this.

Hybrid Heat Pumps

Hybrid systems typically consist of a small heat pump operating in combination with a larger traditional boiler sized for the peak heating load. For hybrid systems, the heat pump is typically installed and used as the lead heat source for part of the year at times of reduced or part load heat demands (i.e. hot water production or for heating during milder external temperatures). The split in annual heating load delivered by the heat pump and by the traditional/ conventional combustion boiler will vary in each application according to the hot water demand, the peak heating demand, the installed capacity of the heat pump, the required heating profile of the building, the original heating fuel type as well as other variables.

The main advantage of hybrid heat pumps is that they are able to operate at the traditional high flow temperatures of conventional combustion boilers. This increases the potential for retaining the existing pipework and heat emitters and thus avoids the cost of replacing these where they have some remaining residual life expectancy. In addition, where a building’s heat requirement exceeds that which can be provided by a reasonably sized and readily available heat pump, demand can be met without the need for supplementary heaters or high cost insulation measures.

Other advantages can include the installation of a smaller heat pump system than might otherwise have been required with a full heat pump only heating system, thereby reducing the corresponding increase in electrical demand / infrastructure to operate the heat pump. Having both an electric heat pump (for at least part of the total load) and a conventional fuel heating systems offers some level of resilience to the heating system and may offer some flexibility regarding optimising running costs subject to variations in the relative price of gas and electricity tariffs.

A key disadvantage of hybrid heat pumps is that there may be compatibility issues between heat pump, boiler, controls, hot water, etc. and there may still be a need to replace pipework and/or radiators., Also, assuming that the boiler is natural gas/LPG/oil-fed, for the immediate future[52] this will still rely on the use of fossil fuels for part of the year. The latter point means that hybrid heat pumps may never benefit from the higher SCOPs compared to a traditional boiler over the full year of which they are capable.

Other disadvantages include the potential additional capital cost (which may require the purchase of compatible boiler and hot water tank) and the physical space required to have both a conventional combustion boiler as well as an accompanying new heat pump system and components. There will also be a more complicated heating controls system required to enable both heating sources to operate together and optimised to give the best performance throughout the whole year. Due to the requirement for additional heating system components and interfacing associated with hybrid heat pump systems, more internal pipework connections /valves /more complex

[50] Advancements in technology may further improve high temperature heat pump SCOP figures in the future, as too would SCOP figures for heat pump systems generally.
[51] The range of high temperature heat pumps available may increase in the future as manufacturers continue to develop their product ranges.
[52] In addition to the use of heat pumps & electrification of heating as a strategy for heat decarbonisation in the longer term there may be proposals for decarbonisation of other fuels for local combustion, e.g. “green / clean” hydrogen, biomethane, etc., however these alternatives are not commercially available at scale at present.

controls, the installation costs for hybrid systems can be greater depending on the selected system and the existing pipework configuration.

Possible Application For The Use of Hybrid Systems

There may be some scenarios where a hybrid heat pump may be more advantageous, in larger domestic applications with a higher heating load (even after applying fabric improvement measures), where the costs of upgrading to a three-phase supply may be very significant, a hybrid system might be more cost effective as well as potentially offering some reduction in carbon dioxide emissions at current levels of grid decarbonisation. Such scenarios would require an in-depth and detailed investigation to determine the most appropriate solution for each particular application.

9.2 Heat Pump Performance and Efficiency

The GLA study only considers heat pumps when operating in heating mode as this is considered the 'renewable' element of heat pump use. Heat pumps for cooling are effectively air-conditioning.

The DfE have reviewed several real-life studies in an attempt to establish Heat Pump Seasonal Coefficient of Performance (SCOP) efficiencies and Seasonal Performance Factors (SPF). COP (Coefficient of Performance) is a measure of efficiency. The efficiency of any machine or system can be calculated as the ratio of amount of work done by the machine to the amount of work given to the machine. In the case of a heat pump, its efficiency is the ratio of useful heat energy produced to electrical energy consumption. A COP of 2.5 means that the heat pump supplies 2.5 times as much heat energy to the system as it consumes in electrical energy. Where COP gives us efficiency of a heat pump at any given time, SPF gives us the same but for annual performance of the heat pump: SCOP and SPF are therefore the same and can also be referred to as the Seasonal Energy Efficiency Ratio" (SEER). Results of the DfE review are as follows:

- Energy Saving Trust Heat Pump Trial (2008-2013) found an SPF for ASHP of 2.45 and GSHP of 2.82.
- Department of Energy & Climate Change, Renewable Heat Premium Payment (RHPP) (2017); found an SPF for ASHP of 2.4.
- The BEIS BUS Scheme utilises an SPF for ASHP of 2.8.

The GLA study results are summarised in Table 4.01 within the report and are shown below in Figure 6.

Figure 6: Extract (Table 4.01) Showing Range of Reported Heat Pump Efficiency Data[53]

SPF_{H2}
SPF_{H3}
SPF_{H4+}

Data Source	Heat Pump Type			Confidence
	Air-air	Air-water	Ground-water	
Field Trials				
EST Field Trials 1		1.20 – 2.20	1.55 – 3.47	*
EST Field Trials 2		2.00 – 3.60	2.00 – 3.82	**
RHPP Detailed Analysis Report*		2.33 – 2.95	2.81 – 3.14	**
Fraunhofer WP-Effizienz		2.50 - 3.60	3.00 – 5.20	***
Fraunhofer WP im Gebäudebestand		2.20 – 3.10	2.80 – 3.60	***
SEPEMO-Build	3.30 - 3.80	3.00+	4.00+	***
Public Authority Decisions (EU/UK)				
Commission decision 2013/114/EU	2.60	2.60	3.50	**
DECC RHI Evidence Report RAAHP's	2.80	2.60	2.90	**
Manufacturer Test Data (EN14825:2016)				
Daikin	3.50 - 5.90	2.60 - 4.39		**
Mitsubishi	3.90 - 5.20	3.19 – 4.12	3.37 – 5.09	**
Panasonic	3.80 – 4.90			**
Kensa			2.94 – 4.69	**
Nibe	3.82 - 4.16	3.75 - 5.05	3.30 – 5.20	**

Table 4.01 – Range of reported heat pump efficiency data.
Please refer to Appendix C for an explanation on the different system boundaries H2, H3 and H4 and to Appendix E for additional information on the data sources. Please note that the RHPP data should be treated with care as its robustness has been questioned.*

[53] Low Carbon Heat: Heat Pumps in London, Greater London Authority

The results from these studies identify a SCOP at different specific flow temperatures and suggest a SCOP between 2.5 and 3.0 for an Air to Water Heat Pump.

Figure 7 is reproduced from the Low Carbon Heat: Heat Pumps in London (2018) report.

Figure 7: Extract (Table 4.02) Showing Range of Reported Heat Pump Efficiency Data[54]

Heat pump type	Efficiency at specific flow temperature (SCOP)					Typical average efficiency
	35˚C	45˚C	55˚C	60˚C	65˚C	
air-air	300%	-	-	-	-	300%
air-water	340%	300%	250%	210%	170%	260%
ground-water	385%	365%	335%	305%	285%	320%

Table 4.02 – Heat pump efficiencies (SCOP) used in this study[10]

9.2.1 Approach to Heat Pump Performance and Efficiency Adopted in Policy Tool

Differences in the flow temperature assumed when testing the seasonal coefficient of performance (SCOP) leads to different findings, as heat pumps work more efficiently when supplying heat at lower temperatures. A SCOP of 2.80 has been initially set and applied within the tools to reflect the BEIS BUS scheme criteria, as well as recent developments within heat pump technology and manufacturer's latest information[55]. This value can be altered and updated within the tools to reflect higher or lower SCOP due to any technological changes that might occur in the future.

For the DfE tools, it is assumed that the Air Source Heat Pumps (ASHPs) are operating at a flow temperature of 55°C. A flow temperature of 55°C is a common operating condition offering a balance between good system performance (possible SCOPs greater than 3.0) and heat emitter performance, and also aligns with updates to England Building Regulations Approved Document Part L (2021), where replacement of heating systems now requires that pipework and radiators are capable of operating effectively at these temperatures.

9.3 Heat Pump Sizing

The following comments have been raised by some commentators[56] in relation to heat pumps. The responses to each perception from the Energy Saving Trust (EST) are included in *italics*.

- **"Heat pumps are not efficient during cold winters"** – *"The efficiency of an air source heat pump will gradually reduce as the outside air temperature falls. However, they are still capable of extracting heat from the air when temperatures are as low as -15°C."*
- **"A heat pump can only be installed in new houses"** – "*Heat pumps can be installed in most properties – regardless of the type of building or how old it is. Modern heat pumps can easily be fitted into different property types – from semi-detached houses to high rise flats. Air source heat pumps are similar in size to an air conditioner compressor and can be a great solution for retrofitting an older or outdated heating system in your home."*

  "You should always check whether you require planning permission from your local planning authority before installing any new renewable system, especially if you live in a conservation area or listed building."

[54] Low Carbon Heat: Heat Pumps in London, Greater London Authority
[55] Manufacturer information includes; Daikin, Mitsubishi, Grant.
[56] Setting the record straight on heat pumps - Energy Saving Trust

For a heat pump to work at its most efficient, buildings should be well insulated to prevent as much heat from escaping as possible. A building that is poorly insulated will require a larger heat pump to make up for the heat loss, and this would cost more money to install and to run.

The Microgeneration Certification Scheme (MCS)[57] is a standards organisation. They create and maintain standards that allows for the certification of products, installers, and their installations, which also includes parameters regarding heat pump system design and sizing. Associated with these standards is the certification scheme, run on behalf of MCS by Certification Bodies who hold UKAS accreditation to ISO 17065. MCS certifies low-carbon products and installations used to produce electricity and heat from renewable sources. The scheme evaluates installers under robust criteria for each of the microgeneration technologies, and products, allowing consumers greater protection and ensuring the effective spend of grants. MCS is a mark of quality. Membership of MCS demonstrates adherence to these recognised industry standards, highlighting quality, competency, and compliance.

The standards for heat pumps taken from the Microgeneration Certification Standards: Domestic Heat Pumps – A Best Practice Guide are presented in Figure 8 and Figure 9;

Figure 8: Extract MCS Installer Standard for Heat Pumps[58]

MCS Reference	Description	Version No	Issue Date
MIS 3005	Requirements for MCS contractors undertaking the supply, design, installation, set to work, commissioning and handover of microgeneration heat pump systems	5.0	28.04.2017
MIS 3005-D	The Heat Pump Standard (Design)	1.0	01.12.2021
MIS 3005-I	The Heat Pump Standard (Installation)	1.0	01.12.2021
MGD 007	Heat Pump Reference Information and Tools (contains: Domestic Hot Water Cylinder Selection Guide; GSHP Hydraulics Design Guide; Heat Emitter Guide and Ground Loop Sizing Tables)	1.0	14.07.2021
	Domestic Heat Pumps – A Best Practice Guide		14.07.2020
	MCS Domestic RHI Guidance (due to be withdrawn on 1st April 2022) For reference, please see: Ofgem Domestic RHI Metering Guidance		
	Heat Pump Installation – Installer Handover Checklist		
MCS 031	Heat Pump System Performance Estimate Template	2.1	31.07.2019
	MCS Heat Pump Calculator Use of this tool is optional, as others are available, and MCS cannot guarantee that it is error-free. Users of the tool do so at their own risk.	1.10	07.04.2021
	Heat Pump Calculator User Guide	1.2	12.07.2019
CC 002	Heat Pump Compliance Certificate Template	3.2	25.07.2019

Figure 9: Extract MCS Product Standards for Heat Pumps[59]

MCS Reference	Description	Version No	Issue Date
MCS 007	Product Certification Scheme Requirements: Heat Pumps	6.1	01.12.2019
MCS 026	SCOP and SSHEE Calculator	1.0	01.05.2015
MCS 027	SPER and SSHEE Calculator	2.1	22.07.2019
MCS 028	DHW Calculator	1.1	29.07.2019
MCS 021	Heat emitter guide for domestic heat pumps	2.2	21.06.2019

[57] Microgeneration Certification Standards: Domestic Heat Pumps – A Best Practice Guide
[58] MSC Installer Standard for Heat Pumps
[59] MCS Standards Tools Library

The MCS report includes reference to documents that set the parameters on how a heat pump system should be designed and installed. These criteria concern sizing of heat pumps, site or space, heat loss through fabric, distribution systems and different types of heat pumps.

MCS advise that the Best Practice Guide should be used in conjunction with other guides such as the CIBSE Domestic Heating Design Guide[60], BRE Design of Low-Temperature Heating Systems[61], BESA Low Temperature Heating Guide[62], and various guides issued by the Ground Source Heat Pump Association (GSHPA)[63].

When sizing a heat pump, the MCS document encourages consideration of heat losses particularly in relation to the age of the property, its construction and any alterations undertaken, hot water demand, the design conditions e.g. manufacturer stated heat pump size checked against minimum outdoor design air temperature and intended flow temperature, heat emitters and pipework. The MCS document outlines a number of pre-installation assessments and considerations that a heat pump installer should undertake against the proposed heat pump make /model to be installed:

- Calculation of hot water demand - A consensus on how to adequately size the heat pump for domestic hot water production does not currently exist however BS EN 16147 standard is used to help with deciding loads for DHW production.
- Check heat pump capacity at specific design conditions. The size of the heat pump as noted by the manufacturer should be checked against the minimum outdoor design air temperature and the flow temperature that the system is designed to run at.
- Systems design and pipework sizing. There are some guidelines and tips of how to design the system and size the pipework so there is the correct flow of water around the building based on what should be achieved - e.g. space heating only, hot water only or a combined service.
- Check of the control options based on time and/or temperature, weather compensation, optimised control, and hot water control.
- Optimise the unit and system's efficiency.
- Check specific requirements of heat pump units and systems like minimum system water content, ASHP location to allow for adequate air flow across the unit and minimum sound transmission, ground conditions for a GSHP array (possible use of a thermogeological survey report to inform input data), controls for hybrid systems and choosing fuel tariffs.

When the system is finally installed, there are typical areas which need attention. Some of them include space for access, correct size pipe runs, heat emitters hydraulically balanced and noise issues. Finally, the report suggests operation and maintenance advice should be provided to end users and provides calculations for some items such as pipe sizing.

A study authored by Etude in September 2018[64] was commissioned by the Greater London Authority (GLA) to identify the implications of a widespread uptake of heat pumps in London's new apartment blocks and commercial developments.

This study adopts the same approach to estimating the quantitative impact of heat pumps on energy demand and carbon savings as per the GLA study, using energy demand data from Part L modelling results to check the carbon savings impact of heat pumps against other technologies. The Part L/National Calculation Methodology (NCM) that is used is required for demonstrating compliance with the Building Regulations. The modelling in the GLA study has been done in accordance with the GLA guidance document for estimating Part L emissions, e.g. the Target Emission Rating (TER) is based on a gas boiler. However, the Part L/NCM methodology is a Building Regulation compliance tool and the results often do not accurately represent actual energy usage in buildings.

The GLA study also includes an assessment that uses benchmarked predicted total energy consumption data in order to assess the impact of heat pumps against a more realistic energy demand. This is to estimate the potential actual carbon reduction benefits of heat pumps in operation. The benchmark data (regulated and unregulated energy consumption) has been taken from CIBSE Guide F for commercial buildings and from Passive House Planning Package (PHPP) modelling for residential buildings. Benchmark data from CIBSE Guide F has also been reduced by 25% (based on Etude's project experience[64]) to account for recent improvements in the energy performance of new buildings, an overview is shown in Figure 10.

[60] CIBSE Domestic Heating Design Guide
[61] BRE Design of Low-Temperature Heating Systems
[62] BESA Low Temperature Heating Guide
[63] Ground Source Heat Pump Association (GSHPA)
[64] Low Carbon Heat: Heat Pumps in London, Greater London Authority

Figure 10: Extract (Table 6.04) CIBSE Guide F[65]

	Benchmark Source / CIBSE Guide F Reference	Space Heating Demand (kWh/m²)	Hot Water Demand (kWh/m²)	Electricity Demand (kWh/m²)
Residential	PHPP Modelling	30	30	40
Primary school	Education, Primary (good practice)	50	10	40
Hotel	Hotels, Holiday (good practice)	90	15	20
Office	Type 4 Office (good practice)	80	10	100

Table 6.04 – Benchmark data used for energy assessment

9.3.1 Fabric of Buildings

In the Minutes of a separate Evidence Report[66] to the Committee for the Economy, the Heating and Hot Water Industry Council noted the following:

> *"The industry supports the view that building fabric needs to be addressed first before a heat pump is installed. Upgrading the fabric to a minimum level ensures that the dwelling heat loss is reduced to a level required by the heat pump to achieve the efficiency and comfort required. In this way, the appliance can be sized and fitted correctly to minimise the initial consumer outlay and maximise the energy savings obtained from lower fuel running costs.*
>
> *As part of the current Renewable Heat Incentive (RHI), BEIS recommend a loft insulation depth of 200mm and fitted cavity wall insulation (where applicable), as per the home Energy Performance Certificate (EPC) (with only a small number of insulation exemptions)[67]. BEIS do not insist on the same treatment for a non-RHI installation, risking a poor consumer return. According to leading experts and heat pump proponents, badly insulated and draughty homes leak heat in sufficient volume to seriously impinge on the performance of a heat pump.*
>
> *It is suggested that homes with solid walls and single glazing should not consider heat pump technologies. There are known issues when designing systems of being overly cautious when sizing the heat pump capacity. The tendency is to oversize appliances, with the aim to provide the best performance of the heat pump. However, this can be to the detriment of the consumer, with over-sizing leading to higher up-front purchase costs and lower efficiency gains than would otherwise be expected. It is therefore good practice to undertake a full heat loss calculation prior to installation, as per the requirements of the current RHI."*

A report produced by Delta on behalf of BEIS[68] investigates electric heating technologies including low and high temperature air source heat pumps, ground source heat pumps, direct electric heating and storage heaters. The report *'identifies how this current technical potential can be improved by making thermal upgrades to different housing types to enable the installation of different electric heating technologies'.*

The before and after U-values used in Cambridge Housing Model (CHM) assessment for three different insulation improvement interventions (loft, wall and floor) are shown below. The models were run for different house types against the baseline levels of insulation shown in Figure 11.

[65] CIBSE Guide F
[66] Heating and Hot Water Industry Council (HHIC) Minutes of Evidence Report - Committee for the Economy
[67] Renewable Heat Incentive (RHI)
[68] Technical feasibility of electric heating in rural off-gas grid dwellings

Figure 11: Extract Summary of U-Values Used within Cambridge Housing Model (CHM)[69]

Insulation type	Before insulation		After insulation	
	U-value [W/m²K]	CHM coding	U-value [W/m²K]	CHM coding
Cavity wall	1.60[a]	External wall construction: 9	0.65[b]	External wall construction: 10
Solid wall (including wall construction defined as "other" with no further description)	1.70[c]	External wall construction: 3	0.60[d]	External wall construction: 4
Loft, pitched roof	> 0.16 (0 mm insulation has a U-value of 2.3 W/m²K)	Loft insulation: <9	0.16	Loft insulation: 9
Room in roof	2.3 – 0.25 (depending on age of house)		0.18	
Floor (all assumed to be solid floor due to no additional information)	0.26		0.20	

[a] updated in line with revised values used for solid wall insulation
[b,d] based on BEIS best practice (already used into CHM)
[c] Upper range of value of 1.3 +-0.4 found by Li et al (2015)[32]

The impact of loft insulation level on energy savings is provided in Figure 12. Whilst the graph demonstrates high initial energy saving potential from the addition of low levels of thermal installation, where there was little or no existing thermal insulation, energy savings are still possible up to 250 mm of thermal insulation and beyond.

Figure 12: Extract (Figure 19) Showing Energy Saving With Added Loft Insulation[70]

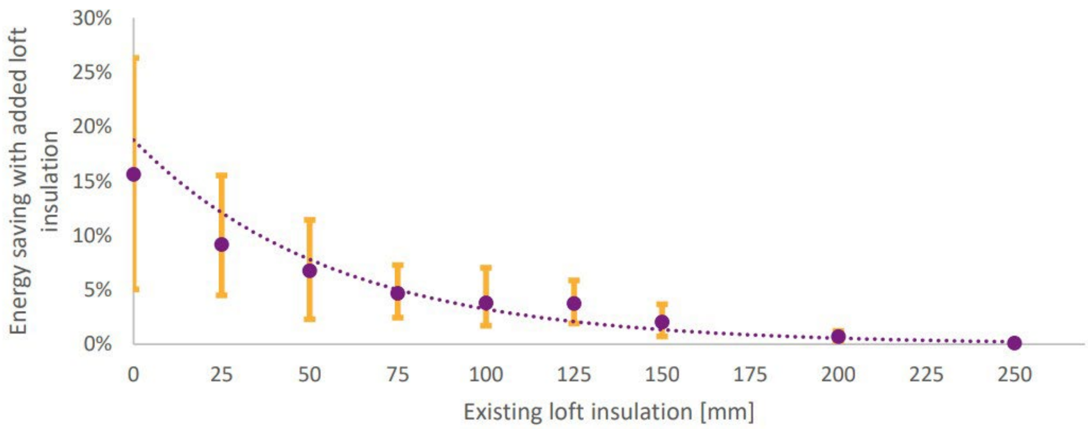


Figure 19: Exploring where to put the cut off in the 'high' and 'low' loft insulation bands – energy saving versus loft insulation thickness. The purple circles show the average energy savings at each initial level of loft insulation and the yellow bars show the range between the 10th and 90th percentile of houses at each initial level of loft insulation. Graph based on outputs from the CHM for the current work.

A BRE report[71] on in-situ measurements of wall U-values in English housing provides the average measured U-values for solid and cavity walls in dwellings, as shown in Figure 13. The figures are broadly in line with the values used in this study (refer to Table 18: Fabric Elements' U-Values Based on the NI Building Regulations for Each Age Band) with some small differences due to the database utilised in this study being specific to NI, whereas the BRE data relates to dwellings in England.

[69] Cambridge Housing Model (CHM)
[70] Cambridge Housing Model (CHM)
[71] In-situ_u-values_final_report.pdf

Figure 13: Extract (Table 1) BRE Report on In-Situ Measurements of Wall U-Values in English Housing[72]

Wall type	Number of cases	Measured U-values: mean (standard deviation) W/m²K*	Measured U-values: median W/m²K	*Calculated U-values: mean (standard deviation), W/m²K*	*Calculated U-values: Median W/m²K*	Typical RdSAP U-values[a] W/m²K	Ratio of (Mean measured U-value) / (Mean calculated U-value)	Ratio of (Mean measured U-value) / (Typical RdSAP U-value)
Solid wall, standard[b]	85	**1.57 (0.32)**	**1.59**	*1.90 (0.20)*	*1.92*	**2.1**	*0.83*	*0.75*
Solid wall, non-standard[b]	33	**1.28 (0.42)**	**1.28**	*1.91 (0.49)*	*1.68*	**2.1**	*0.67*	*0.61*
Uninsulated cavity	50	**1.38 (0.30)**	**1.43**	*1.40 (0.11)*	*1.41*	**1.6**	*0.99*	*0.86*
Insulated cavity	109	**0.67 (0.23)**	**0.63**	*0.52 (0.08)*	*0.51*	**0.5**	*1.29*	*1.34*

9.3.2 Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings

The report[73] by Delta Energy & Environment Ltd, December 2018 on behalf of the Department for Business, Energy & Industrial Strategy (BEIS) made use of the Cambridge Housing Model (CHM) which utilises particular inputs, sources and assumptions:

- The heat loss of each dwelling (W/°C) is calculated in the CHM based on the surface area of the dwelling and the U-value of external surfaces (walls, roof, floor, windows).
- The MCS heat emitter guide (MCS 021 Issue 2.1 (2014)) was used to assess if a heat emitter (supplied by a heat pump) is able to achieve an acceptable level of thermal comfort. The guide is incorporated into the latest MIS3005 (Heat Pump Standard, Issue 4.3 (2013)) and provides a basic look-up table to check whether a heat emitter, operating at a given temperature, delivering heat to a room with a certain heat loss (in W/m^2 floor area) will be deemed thermally comfortable to occupants.
- Heat pump SPF and SCOP.
- Maximum household electrical limit.
- Heating technology merit order.
- Practical suitability of electric heating systems - a qualitative assessment matched to a quantitative practical suitability and then assigned a rating e.g. moderate 50%, good 75%, etc.

Unfortunately, the NI study had no access to the CHM and, to follow a similar methodology, would have required sufficient granularity of data on items such as baseline radiator sizes for individual buildings (not achievable within the study). The Delta model makes use of network data supplied by distribution network operators (DNOs) based in England and Wales (see section 5.2 of this study) including customer numbers, transformer maximum demand reading data and heating technology specific load profiles. This study did not have access to this data. The Delta study made no quantitative cost or economic assessment of technologies but, if it had, it may have reached very different conclusions to a NI study based on the very different electricity grid charging structures in NI as compared with England and Wales.

There are a significant number of other differences between the studies in terms of methodology. The Delta study excluded consideration of flats and non-domestic buildings and did not evaluate domestic hot water. In most cases domestic hot water heating can be scheduled to avoid times of maximum grid loading and are therefore not influenced by wall and loft insulation. This policy tool assumes that domestic hot water generation will be controlled and not scheduled to coincide within peak heating output from the heat pump.

[72] BRE Report In-situ measurements of wall U-values in English housing
[73] Technical feasibility of electric heating in rural off-gas grid dwellings

9.3.3 Approach to Heat Pump Sizing Adopted in this Policy Tool

For each archetype building a peak heating load assessment was completed based on the size, age and type of building. The heating load assessment was based on an external winter design air temperature of -3^{o}C. This temperature was selected from CIBSE Guide A[74] using the winter data for Belfast (most appropriate data point for Northern Ireland) at the 99.6% exceeded value, i.e. on average the air temperature will be above this temperature for 99.6% of the year.

A system warm up margin of 15% is applied to the heating system to ensure that the building is brought up to the required comfort conditions (typically 20^{o}C) and is achieved within an acceptable time frame. By ensuring that all new or retained heat emitter outputs within all rooms match the actual room heat losses ensures that greater system warm up margins can be avoided which minimises the installed heat pump capacity and prevents oversizing and unnecessary installation costs.

All new heat pump systems are based on the installation of the following minimum system components - external heat pump, Domestic Hot Water (DHW) cylinder, interconnected pipework, wiring between external and internal components, heating controls and ancillaries.

With the inclusion of a DHW storage cylinder, domestic hot water is readily available when required. The DHW storage cylinder can be topped up and recharged by the heat pump over time with the heat pump controls system ensuring that the internal space temperature is sufficiently maintained for periods when diverting from space heating to domestic hot water charging. No additional heating capacity is included for domestic hot water charging. Within buildings with very low heat demands (typically small, modern domestic buildings) a minimum heat pump heating capacity of 3kW is applied to ensure domestic hot water demand can be provided.

For domestic applications the heating output of Air Source Heat Pumps (ASHPs) was limited to 16 kW (nominal). This closely aligns with the upper end of manufacturer's equipment ranges targeted at domestic applications and covers the vast majority of domestic buildings, i.e. the output limit is generally achievable with a standard or single phase domestic electricity supply. For greater heat outputs, manufacturers typically offer a different range of units requiring a three-phase electrical supply (not generally installed within typical domestic buildings).

For non-domestic applications the heating outputs of ASHPs was limited to 45 kW (nominal capacity) reflecting the upper threshold of this study. This also reflects the wider prevalence of three phase electrical supplies within larger commercial buildings.

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For non-domestic applications the heating outputs of ASHPs was limited to 45 kW (nominal capacity) reflecting the upper threshold of this study. This also reflects the wider prevalence of three phase electrical supplies within larger commercial buildings.

9.4 Modelling Approach

9.4.1 Domestic Buildings

The NI EPC dataset shows seventy-three unique age bands for properties (including unknown age of the building). Fifty of the unique bands show one year, e.g. 2004, with the remaining age bands showing three parallel age categories. The age bands are shown, along with the approach taken to consolidate the data into three age bands. Where a specific year of construction has been provided (which is common with newer homes), the EPC has been allocated to the relevant age band.

There are three age band categories in the EPC dataset with category two being used in this study. Each age band represents a wall construction type. The EPCs that have category one or category three age bands have been reassigned to category two as per the colour coding in Table 16.

[74] CIBSE Guide A – Environmental Design (2015)

Table 16: Age Band Categories in the EPC Dataset

Age Band Category One	Number of EPCs	Age Band Category Two	Number of EPCs	Age Band Category Three	Number of EPCs
Pre-1900	1,050	Northern Ireland: before 1919	30,539	Northern Ireland: 2007 onwards	6,293
1900-1929	467	Northern Ireland: 1919-1929	16,733		
1930-1949	676	Northern Ireland: 1930-1949	22,942		
1950-1966	2,144	Northern Ireland: 1950-1973	111,580		
1967-1975	445	Northern Ireland: 1974-1977	23,169		
1976-1982	686	Northern Ireland: 1978-1985	35,727		
1983-1990	582	Northern Ireland: 1986-1991	29,503		
1991-1995	1,248	Northern Ireland: 1992-1999	40,521		
1996-2002	2,364	Northern Ireland: 2000-2006	51,101		
Post-2006	1,683	Northern Ireland: 2007-2013	9,208		
		Northern Ireland: 2014 onwards	616		

Age band category two is used within this study and EPCs from the other categories are updated in line with the colour coding show in Table 16. These age bands reflect the main construction differences in the UK building stock, which are:

- Solid brickwork wall for pre-1919 stock.
- Uninsulated cavity wall for 1950-1978 stock.
- Insulated cavity wall (with different levels of insulation) for every age band after 1978.

The age band between 1919 and 1949 is a transition period where building cavity walls and solid brickwork are used. Therefore, this age band was processed separately based on the modelling of the pre-1919 and 1950-1973 age bands by splitting the building stock as 56% for solid wall and 44% for cavity walls respectively (as shown in Table 17).

Table 17: Dwellings Wall Types in EPCs Dataset for 1919-1929 and 1930-1949 Age Bands

		EPC Numbers			
		1919-1929	**1930-1949**	Total	
Cavity Wall	Cavity wall, as built, insulated (assumed)	76	70	16,480	44%
	Cavity wall, filled cavity	336	6,259		
	Cavity wall, as built, no insulation (assumed)	892	8,678		
	Cavity wall, as built, partial insulation (assumed)	19	23		
	Cavity wall, with internal insulation	11	61		
	Cavity wall, filled cavity and internal insulation	5	24		
	Cavity wall, with external insulation	2	8		
	Cavity wall,	0	16		
Solid Brick Wall	Solid brick, as built, no insulation (assumed)	13,062	6,195	20,909	56%
	Solid brick, with internal insulation	975	598		
	Solid brick, as built, insulated (assumed)	5	5		
	Solid brick, with external insulation	31	27		
	Solid brick, as built, partial insulation (assumed)	5	6		

Window glazing areas remain constant across the age bands up to 2006. The 2007-2013 and 2014-present age bands include window U-values of the various relevant Building Regulations.

Table 18, Table 19Table 20 present the u-values for the base model for each building type per age band. Multiple modelling variations based on the agreed interventions were run on these base models. The interventions were based on Northern Ireland Building Regulations, Part F (Consultation) 2021.

Table 18: Fabric Elements' U-Values Based on the NI Building Regulations for Each Age Band

Construction Name	**External Wall U-value (W/m^2K)**	**Roof U-value (W/m^2K)**	**Ground floor U-value (W/m^2K)**	**Window U-value (W/m^2K)**	**Additional Improvements**

Pre 1919 (or pre-1977 solid brick wall construction)	1.7	2.3	0.66	2.8 (double with unknown install date)	
1950-1977 (or pre-1977 cavity wall construction)	1.5	2.3	0.66	2.8	
1978-1985	1.0	0.68	0.66	2.8	
1986-1991	0.60	0.40	0.66	2.8	
1992-1999	0.45	0.30	0.45	2.8	
2000-2006	0.45	0.26	0.34	2.8	
2007-2013	0.30	0.16	0.23	2.0	
2014 onwards	0.28	0.16	0.22	1.6	

Table 19: Five Dwelling Archetypes Baseline Model

	Detached	Semi-detached	Mid-Terrace	Flat	Bungalow
Orientation	East/west	East/west	East/west	East/west	East/west
Average Floor Area (m^2)	180.3	97.5	84.8	59.9	104.9
Height (m) (floor to ceiling)	2.4	2.4	2.4	2.4	2.4
Ventilation	Cross natural ventilation	Cross natural ventilation	Cross natural ventilation	Single natural ventilation	Cross natural ventilation
Thermal Bridging	0.15	0.15	0.15	0.15	0.15
Open flues/ chimneys	0 and 1	0 and 1	0 and 1	0 and 1	0 and 1

Table 20: Proposed Interventions for the Domestic Buildings

Proposed Intervention	Intervention	Modelling Assumptions
Basic-cost interventions	Roof - increase loft insulation to 270 mm	0.16 W/m^{2}K
Intermediate cost interventions	High efficiency glazing solar shading	1.4 W/m^{2}K[75], g-value of 0.4 Frame ratio of 0.3
Enhanced cost interventions	Solid wall insulation	0.3 W/m^{2}K

For the modelling for the policy tool, pressure test assumptions for each age band are based on Northern Ireland Building Regulations maximum value or, when this was not specified, 15 m^3/m^2-hr @50 Pa. Only two age bands have an improved air permeability, 2007-2013 10 m^3/m^2-hr @50 Pa for 2007-2013 and 8 m^3/m^2-hr @50 Pa for 2014- onwards.

It should be noted that policy tool modelling does not include room-in-the-roof options and hence no pitched roof with insulation at rafters.

[75] Northern Ireland Building Regulations, Part F (Consultation) 2021 suggests that for a window upgrade to be compliant it must have at least a WER Band C, a U-value of at least 1.6 W/m^2.K, or glazing must not exceed a centre pane U-value of 1.2 W/m^2.K. Policy tool modelling assumes an improved window U-value as per the table above.

9.4.2 Non-Domestic Buildings

Table 21 shows non-domestic buildings U-values from the National Calculation Method (NCM)[76] for non-domestic Buildings (construction database for NI). These U-values have been used for the purpose of policy tool modelling.

Table 21: Non-Domestic Buildings U-Values

Construction Age Band	External Wall U-value (W/m^2K)	Roof U-value (W/m^2K)	Ground floor U-value (W/m^2K)	Window U-value (W/m^2K) / g-value	Air Permeability ($m^3/hr\ m^{-2}$)
Pre -1919	1.7 solid brickwork [Note 2]	2.3 [Note 2]	0.66 [Note 2]	2.8 / 0.76 [Note 2]	25
1950-1977	1.7 cavity wall [Note 4]	2.3 [Note 2]	0.66 [Note 2]	2.8 / 0.76 [Note 2]	25
1978-1985 [Note 1]	1.0 cavity wall [Note 4]	0.68 [Note 2]	0.66 [Note 2]	2.8 / 0.76 [Note 2]	25
1986-1991 [Note 1]	0.60 cavity wall [Note 4]	0.4 [Note 2]	0.66 [Note 2]	2.8 / 0.76 [Note 2]	25
1992-1999	0.55 [Note 4]	0.3 [Note 2]	0.45 [Note 2]	2.8 / 0.76 [Note 2]	15
2000-2006 [Note 1]	0.45 [Note 4]	0.26 [Note 2]	0.35 [Note 2]	2.8 / 0.76 [Note 2]	15
2007-2013 [Note 1]	0.27 [Note 4]	0.16 [Note 2]	0.23 [Note 2]	2.0 / 0.72 [Note]	10
Post 2013	0.26 [Note 3]	0.16 [Note 2]	0.22 [Note 3]	1.8 / 0.4 [Note 3]	5 [Note 3]

Note 1: The construction age band is aligned with the construction age bands for NI Building Regulations.
Note 2: Based on the default fabric specifications from the Reduced Data SAP for existing dwellings in NI (RdSAP)
Note 3: Based on the building specification for the notional building (NI Part F, 2012).
Note 4: Based on the default fabric specifications from the SBEM for existing buildings in NI

The following air permeability levels shown in Table 22 are based on the CIBSE Guide A (which inform Non-Domestic EPC Conventions for England & Wales Issue 7.1). The NI equivalent guide for NI does not exist, therefore these levels have been applied to the policy tool.

Table 22: Air Permeability Level Assumptions

Air permeability	Relevance
5 $m^3/hr\ m^{-2}$	Intervention to 2012 Building Regulations (or later),
10 $m^3/hr\ m^{-2}$	Buildings > 500 m^2 built to 2002 Building Regulations (or later),
15 $m^3/hr\ m^{-2}$	Buildings <= 500 m^2 built to 2002 Building Regulations (or later),
15 $m^3/hr\ m^{-2}$	Buildings built to 1995 Building Regulations,
25 $m^3/hr\ m^{-2}$	Buildings built to Building Regulations pre-1995.

There are three intervention scenarios in addition to solid wall insulation that affect heat pump suitability for a non-domestic building as identified Table 23.

Table 23: Proposed Interventions for the Non-Domestic Buildings

Intervention	Modelling Assumptions	Source
Solid wall insulation	0.3 W/m^2K	Technical Booklet F1
High efficiency glazing solar shading	1.4 W/m^2K, g-value of 0.4 Frame ratio of 0.3	Technical Booklet F1/RdSAP[77]
Pitched roof - increase loft insulation to 270 mm	0.16 W/m^2K	Technical Booklet F1
Draught proofing – improving air permeability	10 $m^3/hr\ m^{-2}$	Technical Booklet F1/RdSAP[77]

[76] National Calculation Method (NCM) for Non-domestic Buildings (construction database for NI).
[77] Reduced Data SAP for Existing Dwelling - Appendix S

The following groups of interventions are proposed for the non-domestic buildings:

- Basic Measures: Loft insulation, draughtproofing (around existing windows and doors), cavity wall insulation (where currently an unfilled cavity).
- Intermediate Measures: Basic measures, plus high efficiency glazing solar.
- Enhanced Measures: Basic and in intermediate measures, plus wall thermal insulation.

10. Development of Assessment Tools

10.1 Domestic Buildings Modelling

The full SAP calculation methodology, 2009 version, which is still used in Northern Ireland for Part L compliance and EPC reports is used for modelling this study. A model was created for eight age bands per dwelling archetype. The weather data for West Pennines (this is the single weather location to be used for all locations across the UK) is used, with the modelling methodology based on Standard Assessment Protocol (SAP) and Simplified Building Energy Model (SBEM), with unalterable weather files being intrinsic.

The domestic hot water load is based on a typical daily hot water consumption per person of 45 litres per day[78]. The minimum recommended heat pump capacity for domestic hot water heating outlined within British Standard (BS) 6700 and approved by the Microgeneration Certification Scheme (MCS) was taken into account when selecting heat pump capacity. Table 24 and Table 25 present recommended cylinder sizes for domestic applications.

Table 24: Recommended Sizes for Indirect Cylinders with Limited Stratification (BS) 6700

No of Baths	3 kW HP	6 kW HP	8 kW HP	10 kW HP	15+ kW HP
1 Bathroom	122 litre	88 litre	73 litre	70 litre	70 litre
2 Bathrooms	260 litre	200 litre	131 litre	130 litre	130 litre

Table 25: Further Detailed Manufacturers' Recommended Cylinder Sizes (BS) 6700

Hot Water Demand	Bedrooms	3 to 6 kW	10 to 15+ kW
1 Standard Bath or Shower	Bedsit / 1 Bed* 2 – 3 Bed	150 180	90 120
	3 – 4 Bed	210	150
1 Bath and En-suite	2 – 3 Bed	210	150
	3 – 4 Bed	210	150
	4 – 5 Bed	250	180
2 Standard Baths **	2 – 3 Bed	210	180
	3 – 4 Bed	210	180
	4 – 5 Bed	250	210
3 Standard Baths **	3 – 4 Bed	300	250
	4 – 5 Bed	300	250
	5 – 6 Bed	300	300

10.2 Non-Domestic Buildings Modelling

To carry out the dynamic thermal simulations of the non-domestic buildings, the industry standard Virtual Environment (VE) software suite, from Integrated Environmental Solutions Ltd (IES) was used. The IES VE is an integrated suite of applications based around one 3D geometrical model.

The proposed building archetypes are modelled using the Simplified Building Energy Model (SBEM) under Part F (2012) to ensure the designs would generally be compliant with that part of the Building Regulations for the baseline scenarios. The NCM calculation methodology is used to estimate energy demand, energy consumption and carbon emissions for various building construction specifications and heat generator types (e.g. gas boiler / oil boiler / heat pump). This allows for identification of the building thermal performance based on building age and supplied fuel type. The buildings are also assessed after applying a range of interventions to improve thermal performance.

The SBEM enables an estimation to be made of the energy performance of buildings and a building's CO_2 emissions (known as the Building Emissions Rate or BER). The use of each space is selected from the list of

[78] Based on the following daily domestic hot water usage per person; five minute shower with a total water flow rate of 9l/min (6l/min hot water, 3l/min cold water) and an allowance of 15 litres / day for hand washing, cooking, general cleaning, etc.

activities as defined in the National Calculation Methodology (NCM) Activity database. Each activity has defined internal gains, heating set points and operational profiles that enable the estimation of the energy performance of the building. The space heating demand of the building is estimated to achieve assumed heating set points and therefore ensure comfort in winter. For hot water, the energy demand is taken as that required to raise the water temperature from 10°C to 60°C based on the demand specified in the activity database. One model per each archetype was created.

The standard CIBSE Test Reference Year (TRY) weather data for Belfast is used that is required for energy analysis and for compliance with the Building Regulations.

10.3 National Level Heat Pump Assessment and Self-Assessment Heat Pump Tools

The following four tools were developed and are outlined below;

- National Level Assessment Tool (Domestic) – Intended to be used by Northern Ireland Government to help assess how many existing dwellings may be suitable for installation of a heat pump heating system. An estimate of the total heat pump installation costs is provided. The full national results can be filtered / broken down and viewed in finer detail as selected against a range of user selected variables including capital expenditure threshold, improvement measure capital expenditure threshold, construction age band, local council area, building type, and existing fuel type.

- National Level Assessment Tool (Non-Domestic) – Intended to be used by Northern Ireland Government to help assess how many existing non-domestic buildings may be suitable for installation of a heat pump heating system. An estimate of the total heat pump installation costs is provided. The full national results can be filtered / broken down and viewed in finer detail as selected against a range of user selected variables including capital expenditure threshold, improvement measure capital expenditure threshold, construction age band, local council area, building type, and existing fuel type.

- Self-Assessment Heat Pump Suitability Checklist (Domestic) – Intended to be used by individual homeowners to help them consider how suitable their home may be for installation of a heat pump heating system. An outline guide to potential heat pump installation costs and recommendations are provided.

- Self-Assessment Heat Pump Suitability Checklist (Non-Domestic) – Intended to be used by individual non-domestic building owners to help them consider how suitable their building may be for the installation of a heat pump heating system. An outline guide to potential heat pump installation costs and recommendations are provided.

As outlined above, peak heat losses and annual heating energy demand were determined for each identified archetype building (five domestic and four non-domestic archetypes modelled) for each of the identified construction age bands (eight) using industry standard software IES Virtual Environment and SAP applying Northern Ireland weather data. These typical heat loss and heat demands were then applied to each building assessment and then adjusted to reflect the floor areas of each building.

The calculated heat loss and heat demand values were used as a basis for assessing operating annual energy consumption within the policy tools. The existing heating fuel, energy consumption, performance of the existing heating plant and new replacement heat pump installation were used in determining annual operating costs and carbon dioxide emissions.

In the absence of any site visit and with only high level/limited information relating to each building, information was obtained from the national EPC data set[79], e.g. building area, building type and age of construction.

The available data for non-domestic buildings did not contain building age data. Within the Non-Domestic Self-Assessment policy tool, the user is prompted to provide this information. However, within the Non-Domestic National Assessment policy tool an age profile was applied to the whole building stock within the Non-Domestic

[79] It should be noted that the EPC data set contained a number of blank fields or discrepancies which were discounted or removed, such as Zero floor area – data removed; Very low floor area (i.e. less than 20m^2), or very large floor area (i.e. greater than 1,000m^2 for domestic building) – data removed; Missing information such as building type, building age – data removed.

EPC data set. This profile was generated based on the building age distributions within the age banding categories aligned to the available domestic building distribution according to location (which consisted of 11 local council areas) and existing heating fuel type.

10.4 Modelling Approach

Since the EPC datasets for domestic and non-domestic buildings only include a fraction of the full building stock, the datasets were scaled up to match the total number of properties in the GIS data for NI (refer to Section 6). The scale factors were calculated and applied based on the total number of each building type in each council area, e.g., the total number of detached houses in Belfast or the total number of offices in Antrim and Newtownabbey.

11. Costs

11.1 Research on Cost of Heat Pump Installations

The following issues have been raised by some commentators[80] and are highlighted in bold below, with the UK Government response thereafter. The comments do not necessarily reflect the position within Northern Ireland.

- **Cost** – The Government has been providing financial support through schemes such as the domestic Renewable Heat Incentive. From April 2022, the Boiler Upgrade Scheme has provided support to households purchasing heat pumps.
- **Fuel Bills** – A well-designed heat pump system should not need to rely on any additional sources of heat, and when installed to the relevant standards and in a well-insulated home, running costs should be comparable to those of a gas or oil boiler. It is true that heat pumps generally have higher upfront costs than gas or oil boilers, but funding support is available to partially offset these costs.

A number of comments have been raised in relation to heat pumps. One of these was that "*Heat Pumps are too expensive*". Energy Savings Trust's (EST) published response was that "*The upfront cost of installing a heat pump can be significant. However, there is some financial support available depending on where you live to help you install a heat pump. For example, the Home Energy Scotland Loan offers up to £10,000 (£2,500 loan plus £7,500 cashback) to Scottish homeowners. You still have to pay fuel bills with a heat pump because they are powered by electricity, but you'll save on the fuel you are replacing*."

The separate paper from the Heating and Hot Water Industry Council (HHIC) fed into the Minutes of Evidence Report[81] by the Committee for the Economy and focuses on the perceived challenges that need to be overcome in order to encourage greater heat pump adoption for decarbonised solutions. These challenges are the upfront costs, the inadequate heating systems that need to be replaced, the high level of heat loss from UK homes, the lack of qualified installers and the lack of consumer awareness.

It is highlighted that for the upfront costs, the whole system replacement should be assessed and not only the heat pump unit. Radiators, cylinder, buffer vessel and pipework should also be considered. The report pointed to required works prior to heat pump installation including wall and roof insulation, double glazed windows and a full heat loss calculation conducted. All new heat pump installations, including emitters, should be considered as appropriate to the reduced flow temperature.

A separate report[82] on Cost-Optimal Domestic Electrification (CODE) was commissioned by the Department for Business, Energy & Industrial Strategy (BEIS) to better understand the cost trade-offs between a variety of energy efficiency and electric heating measures for homes. The study was based on detailed analysis of the English housing stock. Twelve house types were defined, which collectively represent 90% of Britain's twenty-eight million dwellings. The stock analysis utilised data from the English Housing Survey 2014 and was analysed using the Cambridge Housing Model (CHM).

The CODE modelling considered capital costs of installing electric heating and other energy-efficiency upgrades, energy costs, maintenance, and replacement costs. Archetypal houses were modelled to investigate the relative costs of various options from a householder perspective. Optimisation selected the lowest cost set of combinations for each house type, including running costs over 15 years. The report describes how thermal comfort is reflected in the CODE models, along with a description of the weather data used in modelling. Dynamic simulation models for hourly calculations of internal temperature and energy consumption were used for tens of thousands of different combinations of heating systems and energy-efficiency measures. Any combinations that did not achieve thermal comfort settings were rejected. The study also considered the value of flexibility and the potential of different flexibility measures in shifting energy demand.

The CODE project aim was to develop a set of linked dynamic simulation models to explore the cost and energy-use implications of different English house types adopting different forms of electric heating. The models incorporated energy-efficiency improvements to the fabric of homes, thermal and battery storage, photovoltaics, as well as the electric heating systems. They also considered the effect of different electricity tariffs. Heating technologies in the CODE models included:

[80] Heating and Hot Water Industry Council (HHIC) Evidence Report
[81] Heating and Hot Water Industry Council (HHIC) Evidence Report
[82] Cost-Optimal Domestic Electrification (CODE) Final Report, OGL, 2021

- High-Temperature Air Source Heat Pump.
- Low-Temperature Air Source Heat Pump.
- High-Temperature Ground Source Heat Pump.
- Low-Temperature Ground Source Heat Pump.
- Air-to-Air Heat Pump.
- Hybrid Heat Pumps with Gas Boilers.

The report explains the approach developed for classifying the English housing stock into groups, each represented by a representative house type, or 'archetype'. A similar approach was applied to this study. The approach had two phases - classifying according to building form (based on wall to floor and other ratios), and then by construction type (floor, wall, roof and window construction). Both approaches are important drivers of heat loss and hence heat loss parameter. Construction type also affects thermal mass, which is an important factor driving the potential for thermal storage and flexibility in heating demand.

The following findings are also relevant to this study:

- Detailed modelling of energy costs and evidence-based assumptions about capital costs found only small differences in costs over 15 years between low or high-temperature heat pumps, air-to-air heat pumps, or storage radiators. Typically, the difference was only 10% between the highest and lowest cost.
- Identified ranges for Heat Loss Parameter (heat loss per m^2 of floor area, measured in $W/K/m^2$) for each archetype.
- The performance data was captured from an 11 kW Mitsubishi Ecodan Air-Source Heat Pump (COP depending on external temperature for various flow temperatures).
- The relationship between the external temperature and COP for the air-to-air heat pump with different loads.
- The cost of fabric upgrades.
- The cost of heating system upgrades.
- The cost of ancillary heating upgrades, etc.

Whilst the data sitting behind the report was not available, the structure of the CODE models presented in the report or some components of those models (modified to better reflect NI) were applicable to the development of this policy tool. For example:

- The need for inputs used such as heating system parameters, dwelling parameters, thermal fabric parameters, electric tariffs, and capital costs.
- Calculations for heating sizing and hourly energy costs.
- Intermediate outputs such as the size of heating system, hourly internal temperatures, annual electricity consumption, annual electricity costs, and cost-optimal measures.
- Results produced for the cost-optimal measures for each house type, capital expenditure, operational expenditure and the total cost of peak electrical demand for each house type.

The feasibility of installing any heat pump system would depend on achieving thermal comfort.

The study considered costs that directly impact the consumer such as the upfront cost of equipment, and maintenance costs. Future energy system costs in generation or distribution infrastructure that may be required as a result of households switching to different electric heating technologies were not modelled.

Even with that data, the use of the analysis produced by this project would have been limited for the following reasons:

- It is based on the stock from the 2014 English Housing Survey data, which is out of date with respect to insulation and does not reflect the housing stock in NI.
- The capital running costs in GB are different to NI.
- The weather tape utilised in modelling is GB specific and not specific to NI.
- Non-domestic buildings were not modelled and therefore the range of heat pump sizes analysed is insufficient.

Delta Energy & Environment Ltd produced a report in July 2018[83] commissioned by the Department for Business, Energy & Industrial Strategy (BEIS) with the purpose to:

- Provide BEIS with up-to-date information on the installed cost (excluding VAT) of a range of domestic heating measures, including heating controls. This includes providing a detailed breakdown of equipment costs (e.g. heating system, hot water tank, ancillary equipment and radiators) for the different types of heating systems that can be categorised as a single heating measure.
- Provide deeper insight into installation (labour) costs versus equipment costs for various heating technologies, and for different types of installation (e.g. like for like replacement, new build installation, complete heating system retrofit, etc.).
- Present the fully installed cost of different heating systems as a function of the heating measure capacity.
- Present high, low and central estimates for the fully installed cost of each heating measure category.
- To provide greater information and clarity on where installed costs are likely to be affected by delivery under a government scheme.
- Determine the oversizing factor applied to the installation of boilers and heat pumps.

The report included fully installed costs for different types of heating systems outlined within the report including air-water heat pumps and ground-water heat pumps as well as air-air heat pumps. The Delta EE results are shown in Figure 14, Figure 15 and Figure 16.

Figure 14: Extract (Table 5) Installation Costs of Air-Water Heat Pump Systems Based on Data from GB

Table 5: Example total installed price paid by a customer for common types of air-water heat pump installations

Installation description	Cost in pounds (excluding VAT)
8kW air source heat pump (ASHP) fully installed including fittings, buffer tank, cylinder and controls, excluding the heat distribution system	£ 8,750
12.5kW ASHP fully installed including fittings, buffer tank, cylinder and heating controls, excluding the heat distribution system	£ 11,500
16 kW ASHP fully installed including all new fittings, large buffer tank and advanced cylinder and controls (complex system)	£ 14,050
8kW ASHP fully installed including fittings, small buffer tank and cylinder, controls and heat distribution system (new for a smaller house)	£ 14,750
16kW ASHP fully installed including fittings, large buffer tank and cylinder, advanced controls and heat distribution system (new in larger house)	£ 21,550
16kW ASHP fully installed including buffer tank and cylinder and heat distribution system (retrofit system with upgraded existing radiators)*	£ 14,900

* While upgrading existing radiators is much cheaper than installing a new heat distribution system, the issue with just upgrading the existing radiator network is that the time to heat a room will still take longer than if a new system of underfloor heating (downstairs) and radiators (upstairs) were used. In some cases this may translate into an installer recommended a home owner to install a larger capacity heat pump to compensate for this slower heat time.

[83] Technical feasibility of electric heating in rural off-gas grid dwellings

Figure 15: Extract (Table 6) Installation Costs of Ground Source Heat Pump Systems

Table 6: Example total installed price paid by a customer for common types of ground-water heat pump installations

Installation description	Cost in pounds (excluding VAT)
8kW ground source heat pump (GSHP) fully installed including small buffer tank and cylinder but excluding ground works and excluding controls, excluding the heat distribution system	£ 13,200
12kW GSHP fully installed including buffer tank and cylinder but excluding ground works and excluding controls, excluding the heat distribution system	£ 14,850
16kW GSHP fully installed including large buffer tank and cylinder, complex controls but excluding ground works and excluding the heat distribution system	£ 19,000
12kW GSHP fully installed including buffer tank and cylinder and ground works, excluding the heat distribution system	£ 20,850
12kW GSHP fully installed including buffer tank, cylinder, ground works, controls and the heat distribution (underfloor heating downstairs and radiators upstairs) system	£ 27,350

Figure 16: Extract (Table 7) Installation Costs of Air-Air Heat Pump Systems

Table 7: Example total installed prices paid by a customer for common types of air-air heat pump installations

Installation description	Cost in pounds (excluding VAT)
1 bedroom flat (1 x 2 kW for bedroom + 1 x 3.5 kW for lounge) - lower cost of fittings used due to smaller install	£ 2,400
2 bedroom flat (2 x 2kW for bedrooms + 1 x 3.5kW for lounge)	£ 4,000
3 bedroom flat (3 x 2 kW for bedroom + 1 x 3.5 kW for lounge) - large distance between indoor and outdoor units	£ 6,500
4 bedroom house (4 x 2 kW for bedroom + 1 x 5 kW for lounge) - large distance between indoor and outdoor units	£ 8,800

The cost of individual control components is listed in the cost database[83]. The report provides the information on oversizing factors for heat pumps.

The study by Delta was to provide BEIS with the data and insights on the current costs of installing different types of heating measures in domestic properties to inform decision making for policy development. The list of activities and components used in the study are likely to be broadly similar between England and NI but prices, and arguably the size of markets, have changed significantly since 2018. For the NI Heat Pump Tool study, a greater range of technology capacities are required to be considered (up to 45kW).

The data utilised in the project was not available. Given recent increases, costs for this project were NI based and provided by a Quantity Surveyor.

11.2 Running Cost of Heat Pump Installations

A separate report[84], produced by the Building Research Establishment (BRE), summarises the cost of improving dwellings in the Northern Ireland housing stock to an EPC Energy Efficiency Rating (EER) band C and B, and the associated energy savings that can be realised. The Standard Assessment Procedure (SAP) is used as the underlying methodology to model energy efficiency improvements and quantify energy savings in this work.

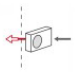
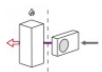
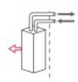
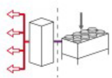
Improvement measures, which focus on installing fabric insulation and upgrading heating systems, were sufficient to improve dwellings to an EER band C. To reach the target band B, further measures were required in the majority of cases. Specifically, the installation of photovoltaic (PV) panels was essential in improving a significant proportion of the stock to Band B. This study is extremely relevant to any NI policy proposals around minimum energy efficiency standards (MEES) in the future (which is based on an Energy Performance Certificate (EPC) rating elsewhere in GB).

For the above 'Cost of Carbon Savings' report, two methodologies were applied to assess an improvement of the dwellings' energy efficiency:

- ***The improvement methodology as detailed in Appendix T of SAP.*** The model was used to calculate the SAP 2012 rating and quantify the energy efficiency improvements realised through the installation of a range of improvement measures. Assigning costs to installed measures allows for an estimate of the total and average cost required to improve dwellings up to a given standard. For each dwelling with an EER band of D or lower, improvement measures were simulated cumulatively, and the SAP rating recalculated after each improvement, until the dwelling reached the threshold for EER band C. Note that in this study upgrading the boiler with a low carbon central heating system measure was assumed in less than 1% of improved dwellings and referred to an upgrade biomass boiler installation where there was previously a solid fuel boiler.
- ***Alternative improvement methodology, that used alternative technologies likely to be employed in the short and medium-term.*** These scenarios have been created to reflect policy considerations around the most feasible routes to improving the NI housing stock in the short and medium-term. The improvements recommended under the medium-term scenarios focus on an increased level of fabric insulation and include the installation of low energy lighting and heat pumps in the measure packages.

The Greater London Authority (GLA) commissioned a report[85] to support the development of an evidence base to inform the implementation of London Plan policies and the final London Environment Strategy publication. In the 2018 Etude report, the capital cost implications for infrastructure, building and dwelling are ranked in Figure 17.

Figure 17: Extract of Capital Cost Implications of Air Source Heat Pumps

Type	Ref	Example	Capital cost implications for developer		
			Infrastructure	Building	Dwelling
AIR SOURCE Small-A1		Monobloc	- -	- - -	+ + + +
AIR SOURCE Small-A3		Hybrid	-	- - -	+ + + + +
AIR SOURCE Small-A4		Compact unit Heat Pump + MVHR	- -	- - -	+ + + + +
AIR SOURCE Medium-A1		Communal air source heat pump to heat interface units (HIUs)	- -	+ +	=

However, these cost ratings are for new developments in London, whereas this study is concerned with the retrofit of buildings in NI. The building archetypes and the cost levels employed are not reflective of those employed in this study. Also, as mentioned previously in this report, the charging structures for electricity grid connections work

[84] Cost of carbon savings in Northern Ireland's housing stock (nihe.gov.uk), Retrofitting Energy Efficiency Measures to Achieve EER Bands C and B: Modelled Using Data from the Northern Ireland House, Condition Survey 2016,
[85] Low Carbon Heat: Heat Pumps in London, Greater London Authority

differently in NI (where costs are based on specific costs and measures which differ for each application, i.e. costs are not socialised) than for England.

The main findings from this project in London from a retrofit context, are that heat pump efficiencies of 250%-350% are likely to be typical, therefore fuel bills could increase or decrease compared to current fuel bills. However, this potential increase can be mitigated and even reversed by using a more competitive electricity tariff or a dynamic time of use tariff[86] or removing the gas standing charge for example. Where a grid gas boiler can be replaced in its entirety, the gas standing charge can be avoided. This has the biggest impact on small properties, where the gas standing charge accounts for a higher proportion of the overall bill. In these cases, the removal of the gas standing charge can make the heat pump the lower cost option in terms of fuel bills, as the electricity standing charge is already being paid regardless of heating technology.

Assessing the financial case for heat pump retrofit:

- The strongest financial cases for a heat pump retrofit are a) buildings heated by direct electric heating and b) buildings with a high demand for cooling (as the heat pump can provide free cooling by a simple reverse).
- A good financial case for a heat pump retrofit can be a) ageing communal and district heat networks in need of upgrade; and b) buildings where major building refurbishments are being undertaken already.
- A marginal financial case for a heat pump retrofit (that will also need additional support required), would be a) gas-heated buildings with good levels of energy efficiency (EPC C or above) or where cost effective energy efficiency will bring the building to an EPC C standard, b) gas heated buildings with low temperature heat emitters and c) buildings that require deep retrofit that are suitable for industrialised, scalable approaches.
- The weakest financial cases, where significant additional funding and policy support are required, are a) buildings that require more extensive energy efficiency improvements (for example in heritage properties) and b) larger commercial buildings with high temperature heat demand and simple gas heating systems.

Whilst some of the considerations identified for the study are useful, given the case studies are in relation to common new commercial and apartment development types in London, the results of the heat pump systems modelled are not directly comparable with this study due to:

- The capacity of heat pumps considered extended only to 20 kW. This policy tool will investigate up to 45 kW. According to the report the heat pumps in the small-scale category (0-19 kW) are typically heat pumps for individual buildings whereas those with a capacity of 20 -170 kW are considered as medium scale or a communal heat pump.
- The study does not propose any optimal design or recommend the installation of a particular heat pump type. This policy tool seeks to adopt the lowest cost route dependant on heat demand and building type, geometry and location.

[86] Northern Ireland does not currently have smart meters and therefore time of use tariffs are not yet available.

11.3 Approach Adopted to Costs

An AECOM quantity surveyor provided installation costs (excluding VAT) for retrofitting air source heat pumps based on a range of output capacities (3 kW up to 45 kW – upper threshold limit of assessment brief), operating at up to 55°C flow temperature and -2°C external winter temperature.

Information was obtained by liaising with a range of heat pump manufacturers[87] and local contractors/installers[88], specific to Northern Ireland in April 2022, for retro-fitting new heat pump installations into existing buildings. The heat pump cost information covers the primary side of the heating system up to the secondary heat distribution pipework circuit and heat emitters including external heating pump, Domestic Hot Water (DHW) cylinder, interconnected pipework, wiring between external and internal components, controls and ancillaries including labour. The cost of installation of an Air Source Heat Pump was applied to each building based on the required peak heating capacity of each building and the results are tabulated in Table 26.

Table 26: Overview of Heat Pump Installation Costs Specific to Northern Ireland 2022

Heat Pump Capacity, kW	Domestic or Small Commercial Range	Heat Pump and Installation Cost Range
3.0	Domestic Range	£9,000-£12,000
4.0	Domestic Range	£9,000-£12,000
5.6	Domestic Range	£11,000-£14,000
7.2	Domestic Range	£11,000-£14,000
8.8	Domestic Range	£12,000-£15,000
11.2	Domestic Range	£12,000-£15,000
12.8	Domestic Range	£12,000-£15,000
18.9	Small Commercial	£14,000-£17,000
22.5	Small Commercial	£15,000-£18,000
27	Small Commercial	£15,000-£18,000
36	Small Commercial	£29,000-£34,000
45	Small Commercial	£30,000-£35,000

For each building archetype, separate costs were established for modification or replacement of the secondary heat distribution systems where necessary. This included installation costs for replacement heat emitters (radiators) and for replacement secondary pipework. The cost of installation was proportioned on a floor area basis referenced against the floor area of each archetype building.

The cost of undertaking the identified fabric improvement measures (basic, intermediate & enhanced) were determined for each archetype building. The cost of installation was proportioned on a floor area basis referenced against the floor area of each archetype building.

- Basic Measures: Loft insulation, draughtproofing (around existing windows and doors), sealing of open chimneys, cavity wall insulation (where currently an unfilled cavity).
- Intermediate Measures: Basic measures, plus high efficiency glazing solar.
- Enhanced Measures: Basic measures, intermediate measures, plus wall thermal insulation.[89]

[87] Manufacturers included; Daikin, Grant, Panasonic.
[88] Heat pump supplier / installers; Bassetts, BL Refrigeration, Aircon.
[89] Additional wall thermal insulation applied externally where possible, except in the case of individual flats or terraced properties where installation of a small / local proportion of the total external surface area would be challenging in practice where internal thermal insulation applied.

The following notes and clarifications apply to the cost information;

- All costs are exclusive of VAT.
- Costs have been included for supply and installation of low temperature air to water heat pumps, associated hot water cylinders and controls at a range of output up to 45 kW.
- Costs are based on works being carried out on an individual basis; no economies of scale have been considered.
- An allowance was included for the cosmetic correction of damage to the area around the installation of the external unit and internal components.
- No allowance has been made for repairs or damp-proof course related works to external walls in advance of dry lining or cladding works.
- No allowance has been made for replacement of existing external doors to domestic or non-domestic properties (draft proofing measures only).
- No allowance has been made for any additional ventilation requirements due to increased air tightness.
- Costs for smart controls and metering have not been included.
- A 10% contingency has been included in the estimated costs.

The following costs (which are too bespoke to quantify) are excluded:

- Costs associated with upgrading incoming electrical supply, if applicable.
- Costs associated with internal redecorating of an entire room, i.e. local cosmetic correction only.
- Additional costs within specific building applications where implementing fabric improvement measures (such as installation of internal wall thermal insulation (Table 27) would necessitate associated internal room alterations, i.e. modifications to existing bathroom suites, kitchen units, internal doorways, etc.
- Additional costs associated with local area around the location of external heat pump units, i.e. landscaping, visual screening, etc.
- Decommissioning or safe disposal of previous heating system components beyond immediate boiler plant, i.e. redundant external oil or LPG storage tanks and pipework distribution, etc.
- Costs associated with any replacement flooring and floor covering necessitated by a requirement to lift existing flooring.
- Costs associated with planning applications and/or Building Control applications were excluded.

An assessment of current heating fuel tariffs (from July 2022) was completed, and these tariffs were applied to determine annual heating energy costs (. These tariffs can be updated within all the tools to enable the results to reflect external changes in the future (acknowledging the recent volatile nature of domestic & non-domestic fuel tariffs).

Table 27: Overview of Fuel Tariff Costs

Fuel	Energy Cost Excluding VAT, (Up to 2,000kWh), p/kWh	Energy Cost Excluding VAT, (Over 2,000kWh), p/kWh
Electricity[90]	21.067	21.067
Gas[91]	13.123	8.991
LPG[92]	10.664	10.664
Oil[93]	9.097	9.097

[90] Electricity Price Comparison Table Effective From 9th May - SSE Airtricity
[91] Firmus Energy Tariff Table – Effective From 3rd May 2022
[92] Global LPG Prices – 4th July 2022
[93] Home Heating Oil Price Checker 7th July 2022

12. Support Schemes

12.1 BEIS - Clean Heat Grant in England & Wales

A number of publicly available documents[94] were reviewed related to the above, as follows:

- Consultation outcome: Clean Heat Grant: further policy design proposals.
- Consultation outcome: Future support for low carbon heat.
- Future Support for Low Carbon Heat: Boiler Upgrade Scheme - Government response to Clean Heat Grant proposals within 'Future support for low carbon heat' consultation.

12.1.1 Consultation to the Clean Heat Grant proposals

The primary objective of the Boiler Upgrade Scheme (previously referred to as the Clean Heat Grant), is to incentivise and increase the deployment of heat pumps by providing targeted support to the supply chain prior to the introduction of proposed regulatory and market-based policy levers. The primary existing support scheme for low carbon heat, the domestic Renewable Heat Incentive (RHI), closed to new participants in March 2022. The Boiler Upgrade Scheme was launched in England and Wales in Spring 2022.

The 'Future Support for Low Carbon Heat' consultation sought views on several proposals on the scheme including:

- Appropriate grant levels for eligible technologies and how grants could be best delivered.
- How the scheme budget could be controlled to ensure support for the sector is maintained.
- Consumer protection and features of any audit and compliance regime.

12.1.2 Future Support for Low Carbon Heat: Boiler Upgrade Scheme - Government Response to Clean Heat Grant Proposals within 'Future support for low carbon heat' Consultation

The government response is set out below (the relevant parts for this project are highlighted in bold):

- The government proceeded with the development of the Boiler Upgrade Scheme which launched in May 2022. The scheme will provide capital grants to support the installation of Air Source Heat Pumps (ASHPs), Ground Source Heat Pumps (GSHPs) and biomass boilers in domestic and non-domestic buildings. New build and social housing will not be eligible for support under the scheme, however domestic custom builds will be eligible.
- In response to stakeholder feedback and recent market evidence, the Boiler Upgrade Scheme will provide grants of £5,000 towards the installation and capital costs of ASHPs and biomass boilers, and grants of £6,000 for GSHPs. The scheme will support systems **up to a capacity limit of 45 kWth**.
- With the exception of custom-build properties, heat pumps will only be eligible where they replace existing fossil fuel systems or direct electric systems and must have a minimum SCOP of 2.8.
- Biomass boilers will only be supported in rural areas and where they replace existing fossil fuel systems, where that system is not fuelled by mains gas, or direct electric systems.

Given the challenges presented to heat pump installations around replacement pipework and radiators, it is interesting to note that **the scheme will not support fossil fuel hybrid systems.**

All **installers** participating in the scheme must be **MCS certified** and members of a Consumer Code that ensures customers are protected by a Trading Standards Institute Approved Code of Practice.

[94] Future Support for Low Carbon Heat: Boiler Upgrade Scheme

Building on the existing requirements of the domestic Renewable Heat Scheme (RHI), which utilise Energy Performance Certificates (EPCs) as the basis for the check, the UK government proposes that:

- All applicants must hold a valid Energy Performance Certificate (EPC) in relation to the building. This typically means that the EPC should be one which has been issued in the last 10 years.
- To be eligible for the Boiler Upgrade Scheme Grant there **must be no recommendations on the valid EPC for loft and/or cavity wall insulation (**there will be exemptions to this requirement, for example in the case of listed buildings or those located in a conservation area).

12.1.3 Approach Adopted

The Boiler Upgrade Scheme (BUS) requires that the insulation exemptions will follow those previously in place on the domestic RHI. The eligibility criteria for the support scheme in England and Wales are:

- The minimum insulation requirements will be based on an EPC rating as a metric for the fabric efficiency with no loft/cavity wall recommendations outstanding.
- Only MCS certified products allowed to be installed.
- A maximum capacity limit of 45 kWth per boiler.
- A minimum SCOP of 2.8.
- The new heating system must replace an existing fossil fuel heating system (such as oil, gas or electric).
- The new heating system must be capable of meeting the full space heating and hot water requirement.
- Cannot receive funding for the replacement of an existing low carbon heating system.
- Eligible system types;
  - Air Source Heat Pumps (ASHPs).
  - Ground Source Heat Pumps (GSHPs).
  - Biomass Boilers.
- Ineligible system types;
  - Hybrid Heat Pumps
  - Air-to-Air Heat Pumps

12.2 ROI Support Scheme for Heat Pumps

The Sustainable Energy Authority of Ireland (SEAI) have produced two documents which are particularly relevant to the support for heat pump installations in ROI, as follows:

- Domestic Technical Standards and Specifications SEAL Contractors Code of Practice[95] version 1.3, 2020.
- The Support Scheme for Renewable Heat Grant Scheme Operating Rules and Guidelines[96].

12.2.1 Domestic Technical Standards and Specifications

This document is a reference for contractors carrying out dwelling energy upgrade works supported by multiple programmes like SEAI's Better Energy Homes, Better Energy Warmer Homes, Deep Retrofit, Warmth and Wellbeing, Better Energy Finance, Energy Efficiency Obligation Scheme and Better Energy Communities Programmes (the "Programme"). It sets out the general competence, standards and specifications that contractors should possess, and adhere to, in carrying out works supported by the various programmes.

The 'Domestic Technical Standards and Specifications' has several sections which set out specific targets when carrying out retrofits in existing buildings. In Section 9 of this document, the Seasonal Coefficients of Performance of a range of heat pumps are examined. For the ROI scheme, the minimum COP for the heat pump is given as 3.0 for space heating for all types and 1.6 for water heating. Also, heat pumps should be designed, sized and installed

[95] SEAI Contractors Code of Practice
[96] SEAI The Support Scheme for Renewable Heat Grant Scheme Operating Rules and Guidelines

to provide at least 100% of the space heating demand and 80% of the hot water demand so as they are eligible for the grants. Heat pumps for cooling purposes are not eligible.

Appendix 2 of the ROI guidance indicates the energy efficiency targets in retrofits as noted in Table 28.

Table 28: Minimum U-values for Several Building Fabric Elements when a Domestic Property is Retrofitted

Measure	U-Value Target After Retrofit (W/m^2-K)
Cavity Wall Insulation	0.35
External Wall Insulation	0.27
Internal Wall Insulation	0.27
Ceiling-level Attic insulation	0.16
Rafter Level Attic or Flat roof Insulation	0.20 (rafter) or 0.22 (flat)
Floor Insulation	0.36 or 0.15 (when there is Underfloor heating)

12.2.2 Overview of the policy paper 'The Support Scheme for Renewable Heat Grant Scheme Operating Rules and Guidelines'

This government funded scheme supports the adoption of renewable heating systems by commercial, industrial, agricultural, district heating, public sector and other non-domestic heat users not covered by the emissions trading system. The scheme aims to bridge the gap between the installation and operating costs of renewable heating systems and the conventional fossil fuel alternatives; and incentivise the development and supply of renewable heat.

The scheme supports a) an installation grant; and b) on-going operational support. The main technical specification requirements among others for heat pumps under this scheme are:

- Seasonal system's efficiency **(**Seasonal Coefficient of Performance - SCOP) to be 2.5.
- Not to use air as a transfer medium for heat with a heat output in excess of 45 kWth.
- In the case of a heat pump that heats water, the heat pump must be capable of supplying hot water at 55ºC and the supplementary hot water heater shall provide stored hot water at 60ºC and prevent the growth of legionella.

Other requirements include an appropriate heat pump location to avoid nuisance to sleeping areas and to allow for requirements such as maintenance access.

In relation to non-domestic buildings the scheme refers to eligibility criteria, among others, in terms of technical specifications for a heat pump system, types of non-domestic buildings that can apply for the grant, minimum fabric efficiency values and space requirements for the system's location.

13. Modelling Scenarios

13.1 National Level Policy Tools

The National Level policy tools developed in this study allow for analysis and assessment of the NI building stock for the installation of heat pumps. The tools include and report costs associated with three levels of improvements measures to the buildings (e.g. fabric improvement) and heat pump installation costs that could assist consumers with their decision in respect of a heat pump installation. Moreover, the results from the models could be used to identify property types that tend to be more suitable for heat pump installations.

Table 29 below shows outputs from the Domestic National policy tool when considering the total building stock in NI. The average capital cost of installing heat pumps only with no improvement measures in domestic properties for all building types is calculated to be £15,503[97]. The total capital cost increases following the inclusion of each of the improvement measures. The average cost of heat pump installation and cost of improvement measures per property is calculated to be; heat pump & basic improvement measures £15,781, heat pump & intermediate improvement measures £21,037 and heat pump & enhanced improvement measures £29,311[98].

Overview of basic, intermediate and enhanced improvement measures;

- Basic Measures: Loft insulation, draughtproofing (around existing windows and doors), sealing of open chimneys, cavity wall insulation (where currently an unfilled cavity).
- Intermediate Measures: Basic measures, plus high efficiency glazing solar.
- Enhanced Measures: Basic and intermediate measures, plus internal or external wall thermal insulation.

Table 29: Domestic National Tool Output for Total Building Stock in NI

	Current Heating System	Heat Pump with No Improvements	Heat Pump & Basic Improvement Measures	Heat Pump & Intermediate Improvement Measures	Heat Pump & Enhanced Improvement Measures
Total Capital Cost of Option (£million)	NA	£12,494	£12,718	£16,953	£23,621
Average Capital Cost of Option Per Building (£)	NA	£15,503	£15,781	£21,037	£29,311
Total Annual Fuel Cost for All Properties (£million)	£1,229	£869	£708	£690	£575
Average Annual Fuel Cost Per Property (£)	£1,525	£1,079	£879	£856	£714
Total Annual CO_2 Emission for All Properties (kt)	2,978	867	707	688	574
Average Annual CO_2 Emission Per Property (kg)	3,695	1,076	877	854	712
Improvement Measures Costs are Cumulative, e.g., the Enhanced Improvement Measures Include the Costs of Basic and Intermediate Measures. **Basic Measures** - Typical cost of upgrading roof insulation and draught-proofing measures. **Intermediate Measures** - Typical cost of replacing windows with high thermal performance glazing plus basic measure cost. **Enhanced Measures** - Typical cost of applying external/internal thermal insulation to walls plus basic and intermediate measures costs.					

Installation of heat pumps with basic improvements is slightly more expensive than installing a heat pump only. However, the results show a noticeable reduction in annual energy costs and emissions after applying the improvement measures; therefore, this scenario is more cost-effective in the medium to long term

[97] Low temperature heat pump, including costs of any radiator or pipework improvements

[98] These are averaged figures meaning that there will be variation in individual property costs either side of this value, i.e. the cost for some properties will lower than these figures and some will be higher.

It should be noted that the current annual fuel cost is based on the applied filters for current space heating fuel within the tool, and the above table includes buildings with all considered fuel types. The proportion of any changes in annual costs when moving from an existing heating plant to a heat pump is different for each fuel and building type specified in the tool.

To demonstrate the tool's functionality, Table 30 presents results for semi-detached properties in Belfast that currently utilise oil for heating. The data shows a significant reduction in carbon emissions after installing heat pumps.

Table 30: Domestic National Tool Output for Semi-Detached Properties in Belfast that Utilise Oil for Heating

	Current Heating System	Heat Pump with No Improvements	Heat Pump & Basic Improvement Measures	Heat Pump & Intermediate Improvement Measures	Heat Pump & Enhanced Improvement Measures
Total Capital Cost of Option (£million)	NA	£275	£279	£375	£577
Average Capital Cost of Option Per Building (£)	NA	£15,838	£16,088	£21,629	£33,249
Total Annual Fuel Cost for All Properties (£million)	£30	£22	£17	£17	£12
Average Annual Fuel Cost Per Property (£)	£1,745	£1,269	£982	£959	£683
Total Annual CO_2 Emission for All Properties (kt)	82	22	17	17	12
Average Annual CO_2 Emission Per Property (kg)	4,704	1,266	980	956	681

Improvement Measures Costs are Cumulative, e.g., the Enhanced Improvement Measures Include the Costs of Basic and Intermediate Measures.

Basic Measures - Typical cost of upgrading roof insulation and draught-proofing measures.
Intermediate Measures - Typical cost of replacing windows with high thermal performance glazing plus basic measure cost.
Enhanced Measures - Typical cost of applying external/internal thermal insulation to walls plus basic and intermediate measures costs.

The Non-Domestic National Tool has similar functionalities and covers the entire building stock for the four non-domestic building archetypes considered in this study (office, restaurant, school and retail, which have a peak heat demand up to 45kW), excluding any buildings that were out of the scope[99].

Table 31 shows the Non-Domestic National policy tool results when considering full building stock, all fuels and Table 32 presents the data for retail shops in Mid Ulster that currently utilise natural gas for heating.

Table 31: Non-Domestic National Tool Output for Total Building Stock in NI (Office, Restaurant, School, Retail)

	Current Heating System	Heat Pump with No Improvements	Heat Pump & Basic Improvement Measures	Heat Pump & Intermediate Improvement Measures	Heat Pump & Enhanced Improvement Measures
Total Capital Cost of Option (£million)	NA	£681	£673	£1,673	£2,022
Average Capital Cost of Option Per Building (£)	NA	£29,626	£29,298	£72,845	£88,024
Total Annual Fuel Cost for All Properties (£million)	£105	£51	£45	£41	£35
Average Annual Fuel Cost Per Property (£)	£4,574	£2,232	£1,938	£1,804	£1,537
Total Annual CO2 Emission for All Properties (kt)	156	51	44	41	35
Average Annual CO2 Emission Per Property (kg)	6,813	2,226	1,933	1,800	1,533

[99] E.g. buildings with higher than 45kW peak heat demand or buildings with both existing air conditioning and electric heating.

Improvement Measures Costs are Cumulative, e.g., the Enhanced Improvement Measures Include the Costs of Basic and Intermediate Measures.
Basic Measures - Typical cost of upgrading roof insulation, draught-proofing measures and cavity wall insulation**.**
Intermediate Measures - Typical cost of replacing windows with high thermal performance glazing plus basic measure cost.
Enhanced Measures - Typical cost of applying external/internal thermal insulation to walls plus basic and intermediate measures costs.

Table 32: Non-Domestic National Tool Output for Retail Shops in Mid Ulster that Utilise Natural Gas for Heating

	Current Heating System	Heat Pump with No Improvements	Heat Pump & Basic Improvement Measures	Heat Pump & Intermediate Improvement Measures	Heat Pump & Enhanced Improvement Measures
Total Capital Cost of Option (£million)	NA	£2	£2	£6	£7
Average Capital Cost of Option Per Building (£)	NA	£48,355	£49,546	£129,594	£151,472
Total Annual Fuel Cost for All Properties (£million)	£0.22	£0.16	£0.15	£0.14	£0.11
Average Annual Fuel Cost Per Property (£)	£4,558	£3,371	£3,129	£2,896	£2,359
Total Annual CO2 Emission for All Properties (kt)	0.43	0.16	0.15	0.14	0.11
Average Annual CO2 Emission Per Property (kg)	9,101	3,363	3,121	2,889	2,353
Improvement Measures Costs are Cumulative, e.g., the Enhanced Improvement Measures Include the Costs of Basic and Intermediate Measures. **Basic Measures -** Typical cost of upgrading roof insulation, draught-proofing measures and cavity wall insulation**.** **Intermediate Measures -** Typical cost of replacing windows with high thermal performance glazing plus basic measure cost. **Enhanced Measures** - Typical cost of applying external/internal thermal insulation to walls plus basic and intermediate measures costs.					

13.2 Consideration of Grant Support

These policy tools allow for the option to set thresholds for heat pump heating system installation, improvement measures and total costs within the results. The thresholds are used to identify the proportion of the buildings that can install a heat pump within the applied improvement measures with a budget equal to or less than the inputted threshold by the user. This functionality can be used to analyse different levels of financial support and the impact on capital costs incurred by the building owners.

As an example, if there was intended to be financial support of £10,000 for domestic heat pumps, assuming this would cover 50% of the total costs, the Domestic National policy tool, would require a capital expenditure threshold to be set to £20,000.

Table 33 shows that with a £20,000 total cost for capital expenditure limit 93%, 44% and 35% of the dwellings can technically install a heat pump with basic, intermediate, and enhanced improvement measurements, respectively. Note that this example is intended to illustrate how the tool can be used and does not infer any future financial support or the amount that may be chosen if support were to be made available.

Table 33: Proportion of Dwellings where a Heat Pump and Improvement Measures with a Budget of £20,000

.		Heat Pump & Basic Improvement Measures		Heat Pump & Intermediate Improvement Measures		Heat Pump & Enhanced Improvement Measures	
Selected Threshold for Total Capital Expenditure Limit	*£20,000*	Number of Properties with Lower Heat Pump and Improvement Measure Capital Costs than the Selected Threshold	Proportion to the Total Selected Number of Properties	Number of Properties with Lower Heat Pump and Improvement Measure Capital Costs than the Selected Threshold	Proportion to the Total Selected Number of Properties	Number of Properties with Lower Heat Pump and Improvement Measure Capital Costs than the Selected Threshold	Proportion to the Total Selected Number of Properties
Bungalow		134,417	89%	53,683	35%	11,709	8%
Detached		92,873	74%	42,305	34%	41,162	33%
Flat		108,662	100%	95,575	88%	69,175	64%
Mid-Terrace		155,443	99%	42,818	27%	11,964	8%
Semi-Detached		256,930	98%	117,138	45%	65,858	25%
Unknown		342	98%	277	79%	196	56%
Total		**748,667**	**93%**	**351,797**	**44%**	**200,063**	**25%**

13.3 Self-Assessment Tools

A separate pair of self-assessment tools have been developed to help a domestic home-owner or non-domestic building owner consider how suitable their building may be for the installation of a heat pump.

The Self-Assessment tools provides the user with an introduction to heat pumps along with background information. The tools highlight areas that need to be considered when thinking about suitability, such as the up-front cost of a heat pump, running costs and potential changes which may be required or recommended for their building.

The Self-Assessment tools are intended as a first step in a process, which is aimed at providing a domestic home-owner or non-domestic building owner with initial information to consider prior to proceeding with a heat pump installation. In all instances the domestic homeowner or non-domestic building owner should contact an appropriately qualified and competent heat pump supplier or installer and arrange a site visit in order to check how suitable their building is for a heat pump.

14. Conclusion

Two different tools have been developed for NI DfE, one for use at a national level to support in considering policy for the retrofit of air source heat pumps, the other to enable building owners and occupiers to evaluate at high level the suitability of their buildings for heat pumps.

In developing these tools, a considerable number of reports, tools, data, models and methodologies have been reviewed. Regulatory frameworks have been considered including the planning system and the process for connecting equipment to the national electricity grid, in order to identify barriers and reflect these within the tools wherever possible.

Regarding the planning system, the existing General Permitted Development Order (GPDO) in NI is likely to be a barrier to the uptake of heat pumps in NI due to a requirement for 30m spacing. Heat pumps intended to be installed in apartments, terraced and semi-detached housing are unlikely to be able to meet this requirement and, without amendment, will require planning permission. This will be an additional cost on top of the heat pump installation.

The intention to review the GPDO in NI is noted and, given that the cost of planning applications will vary, costs for obtaining planning permission have not been included in the policy tool. However, distance options can be user defined within the tool to provide flexibility to the tool user as to what buildings are included/excluded from results. Planning should be noted as an under-estimation of the cost of heat pump retrofit at present as, even if the need for a full planning application is removed, changes to fixed building services, and in some cases accompanied by a renovation of a thermal element, would require a Building Control Notice to which a cost is also attached.

Similarly, costs for upgrades of electrical fusing in properties has been omitted. Research in this topic area is relatively limited. Overall, the research seems to indicate that, as long as a heat pump that is deemed of a domestic size (e.g. of 16kW or less) is fitted, single phase supplies should be sufficient to accommodate heat pump retrofit. It is only very large dwellings and non-domestic buildings that may require greater capacity, with the latter likely to have three-phase already (although SMEs working out of ‘domestic-type’ properties may also face similar problems). There is little in the way of data in NI on this topic at present and so these costs have been omitted from the tool. However, as with the cost of planning applications, it should be noted as a potential under-estimation of heat pump retrofit costs. The costs for these upgrades are more likely to be a barrier in NI than for other parts of the UK as, unlike in Great Britain, such costs are not socialised and are likely to be incurred by the applicant. The other element of the unknown in respect of the electricity grid is the upstream costs if whole geographical areas take up heat pumps. This has not been quantified in the tool and is an area where more detailed research is strongly recommended.

Data about the building stock in NI has been used to inform the tools. Energy Performance Certificate (EPC) data (cleansed), supported by NI Part-F Building Regulations compliance software (Standard Assessment Procedure (SAP) and Simplified Building Energy Model (SBEM)), has provided the basis for most of the assumptions about the buildings and their energy performance, with NI’s OSNI (Geographical Information Systems) database supplying information to enable scaling up.

More comprehensive data (particularly in terms of non-domestic buildings, including Display Energy Certificates (DECs)) would have been of significant benefit to the study. Date relating to the age of construction was also missing from the available non-domestic EPC data. For more detailed aspects of the study, detailed data from the NI Housing Condition Survey might have been helpful to distinguish in finer grain the proportion of buildings that might require upgrades of various forms of fabric, etc. Instead, Part F requirements have informed assumptions about different levels of fabric except where different building elements may have passed their useful life (e.g. windows, etc).

The data obtained enabled building archetypes of different age bands, and therefore different construction types, to be selected for producing baseline energy demands. For dwellings, the selection of archetypes was relatively straight-forward: detached; semi-detached; mid-terrace; bungalow and flat (a mid-level apartment was selected).

The scope of this research considered buildings within the accepted definition of microgeneration (less than 45kW) and so non-domestic building archetypes were also selected. Utilising EPC data, likely peak demands were back-calculated to understand the types of building that might fall into the <45kW range: these included small schools & nurseries; small cafes and retail (possibly ground floors of larger high street buildings); and small stand-alone office type use buildings (e.g. GP/health surgeries, etc).

The buildings selected addressed a significant proportion of the non-domestic stock likely to be suitable for heat pump retrofits, suitability being considered as buildings with wet systems or requiring electrical heating only as opposed to those requiring heating and cooling by way of blown air systems (which were excluded). It is acknowledged that, in selecting archetypes prior to theoretical application of improvement measures, the number of buildings identified as being <45kW is under-estimated.

The heat pumps used for modelling were air to water systems based on their greater universality of application. It may be that, in certain locations, ground and water sources are available with better coefficients of performance, which will increase the assumed capital costs in the tool but will also reduce the ongoing fuel bills. It is assumed that a ground or air source heat pump is unlikely to change any of the assumptions made in the tool about the need for fabric and services upgrades, only the heat exchange interfaces.

In terms of the type of heat pump, mono-block, split, compact and communal systems have been considered, as have hybrid and high temperature heat pumps solutions. For the tool, based on that employed for England's Boiler Upgrade Scheme (BUS), we have employed a seasonal coefficient of performance (SCOP) of 2.8 (although this can be changed by the tool user to see results of utilising other heat sources / heat pump types and efficiencies). Through the application of this SCOP in the tool, with no upgrade measures selected and no restrictive capital or operational ceilings, the technical suitability of heat pumps for all eligible buildings in NI can be viewed.

In the tool the heat pump flow temperature is assumed to be up to 55°C to ensure that a SCOP of 2.8 is achievable. To ensure that the generated heat is effectively delivered and distributed evenly around the property where radiators are used as the heat emitters the tool includes for replacing the existing radiators with new appropriately sized radiators to meet the required heating output at the new system operating conditions.

Some of the literature suggests that hybrid and/or high temperature heat pumps can remove the need and cost of radiator and pipework replacement. Other literature and our own investigations suggest that, even at higher operating temperatures, distribution systems still often require replacement, as well as incur additional costs such as the need for larger heat pumps (as they will be less efficient at higher operating temperatures) and integration with other systems (boilers and hot water tanks, etc). Whilst the SCOP can be amended by the user (to reflect improvements in technology), the tool is based on the new heating source providing a flow water temperature up to 55°C.

It is argued in some quarters that if stand-alone (local electric) heaters can be employed at peak winter temperatures, this can enable heat pump systems to be sized for average winter temperatures whilst still adequately heating the building. The energy efficiencies, carbon and cost savings are dented by such an approach but, because heat pumps are sized to meet peak winter temperatures, the numbers are unable to be tested in the tool.

Because of the importance of minimising additional load on the electricity grid, rather than targeting larger more inefficient heat pumps and/or supplementary heaters, flow rate temperatures of up to 55°C can arguably be most effectively achieved through the improvement of building fabric. This study categorises improvements in terms of basic (draught proofing, etc), intermediate (replacement glazing, etc) and enhanced cost (internal / external wall insulation) measures. The capital cost of measures can be significant but the more capital that is invested, the smaller the heat pump required, the more efficiently the heat pump operates, and the lower fuel bills become.

This study provides the tools for DfE to investigate multiple scenarios to understand if support should be provided and, if so, at what level that support should be. A key question is what metric should be utilised to inform eligibility.

In the absence of Heat Loss indicators (as per the outputs of the ROI's Dwelling Energy Assessment Procedure (DEAP), the tool provides projected energy demands (kW/h/m^2/year heat and hot water, corresponding with EPC outputs from SAP) from a range of building types that can be tested to understand building suitability for heat pump retrofit.

Should DfE be inclined, these energy demands might be used as a basis for underpinning consideration of support measures. However, it has been suggested that the outputs of SAP (and therefore EPC data) significantly under-estimates the actual heat and hot water demands in buildings. If that is the case, the HLI in the ROI could also similarly be less accurate than expected. If this is accepted, a more robust approach may well be to follow England's BUS lead and require a certain energy rating as well as all EPC fabric improvement recommendations being resolved in order to qualify.

This study has identified several recommendations where the quality of the study and the tool could be improved. It is suggested that these gaps be closed wherever possible in order to correctly pitch any support package. Prior to any changes being implemented in buildings, it is also suggested that on-site surveys are conducted to the standards set out in the best practice guides e.g. Microgeneration Certification Scheme guidance (as set out in this study).

Appendix A – Overview of Assumptions

Fabric Improvements

Overview of fabric improvement measures;

- Basic Measures: Loft insulation, draughtproofing (around existing windows and doors), sealing of open chimneys, cavity wall insulation (where currently an unfilled cavity).
- Intermediate Measures: Basic measures, plus high efficiency glazing solar glazing.
- Enhanced Measures: Basic and intermediate measures, plus internal or external wall thermal insulation.[100]

Heat Pumps

Due to its (almost) universal application (it doesn't rely on the presence of a body of water, ground conditions or large physical spaces) a single Air Source Air to Water Heat Pump providing space heating and domestic hot water has been chosen as the preferred type of heat pump in the development of the NI Heat Pump Tool. GSHPs and WSHPs are both likely to give higher SCOPs and therefore reduced running costs and carbon dioxide (CO2) emissions, but the number of installations will be much more limited and bespoke to site, or of greater complexity and higher capital cost.

For the DfE tools, it is assumed that the Air Source Heat Pumps (ASHPs) are operating at a flow temperature of 55°C. A flow temperature of 55°C is a common operating condition offering a balance between good system performance (possible SCOPs greater than 3.0) and heat emitter performance, and also aligns with updates to England Building Regulations Approved Document Part L (2021), where replacement of heating systems now requires that pipework and radiators are capable of operating effectively at these temperatures.

The modelling tool assumes that the installation of a new heat pump system would require a replacement or new domestic hot water heating cylinder compatible with the selected heat pump.

By including a new domestic hot water storage cylinder this ensures that domestic hot water is available when required with the heat pump set to divert to re-charging the storage cylinder when necessary (avoiding simultaneous heating and domestic hot water production). The new domestic hot water storage cylinder would also be correctly sized to match the operating temperature of the new heat pump system.

No additional heating capacity is included for domestic hot water charging. Within buildings with very low heat demands (typically small, modern domestic buildings) a minimum heat pump heating capacity of 3kW is applied to ensure domestic hot water demand can be provided.

All new heat pump systems are based on the installation of the following minimum system components - external heating pump, Domestic Hot Water (DHW) cylinder, interconnected pipework, wiring between external and internal components, heating controls and ancillaries.

A system warm-up margin of 15% is applied to the heating system to ensure that the building is brought up to the required comfort conditions (typically 20°C). By ensuring that all new or retained heat emitter outputs within all rooms match the actual room heat losses ensures that greater system warm-up margins can be avoided which minimises the installed heat pump capacity and prevents oversizing and unnecessary installation costs.

Where the existing building has a wet heating system, the retrofitted heating system assumes that the original heating pipework distribution system will be retained.

For domestic applications the heating outputs of Air Source Heat Pumps (ASHPs) was limited to 16kW (nominal). This closely aligns with the upper end of manufacturer's equipment ranges targeted at domestic applications and covers the vast majority of domestic buildings, i.e. the output limit is generally achievable with a standard or single phase domestic electricity supply. For greater heat outputs, manufacturers typically offer a different range of units requiring a three-phase electrical supply (not generally installed within typical domestic buildings).

[100] Additional wall thermal insulation applied externally where possible, except in the case of individual flats or terraced properties where installation of a small / local proportion of the total external surface area would be challenging in practice and so internal thermal insulation has been assumed.

For non-domestic applications the heating outputs of ASHPs was limited to 45kW (nominal capacity) reflecting the upper threshold of this study. This also reflects the wider prevalence of three phase electrical supplies within larger commercial buildings.

Energy consumption associated with periodic winter defrost cycles of the external heat pump unit have been assumed to be included within the Seasonal Coefficient of Performance (SCOP) values.

Existing Electrical Power Supplies

The assumption was made that existing power supplies in domestic properties comprised of single-phase and assumed to be adequate for heat loads up to this threshold (16 kW).

Beyond 16kW, it was assumed that a three-phase power supply would be required. Whilst the heat pump installation costs are included in the tools, the cost of upgrading the power supply from single to three-phase will be specific to each application. Therefore, the costs of any necessary electrical work are excluded from the assessment. However, the tool does identify the requirement should NI wish to consider these costs further in the future. For non-domestic buildings, an existing three-phase power supply was assumed which would be adequate for a heating load up to the threshold of this study (45 kW).

Available External Space

This policy tool does not contain any specific information on available external space limitations with regard to locating the external heat pump unit. The tool assumes that there will be a vacant section of external wall where a heat pump can be located, e.g. typical domestic location adjacent or below a kitchen window at the rear of the property or to the rear or adjacent to a non-domestic property. For domestic flats installation of a heat pump system would require necessary permission from the landlord, with the installation of external heat pump units serving upper storeys potentially located at ground floor level (adjacent to bin store, car park, cycle shelter, etc.) for ease of installation and health & safety considerations.

Costs

- All costs are exclusive of VAT.
- Costs have been included for supply and installation of low temperature air to water heat pumps, associated hot water cylinders and controls at a range of output up to 45 kW.
- Costs are based on works being carried out on an individual basis; no economies of scale have been considered.
- An allowance was included for the cosmetic correction of damage to the area around the installation of the external unit and internal components.
- No allowance has been made for repairs or damp-proof course related works to external walls in advance of dry lining or cladding works.
- No allowance has been made for replacement of existing external doors to domestic or non-domestic properties (draft proofing measures only).
- No allowance has been made for any additional ventilation requirements due to increased air tightness.
- Costs for smart controls and metering have not been included.
- A 10% contingency has been included in the estimated costs.

The following costs (which are too bespoke to quantify) are excluded:

- Costs associated with upgrading incoming electrical supply, if applicable.
- Costs associated with internal redecorating of an entire room, i.e. local cosmetic correction only.
- Additional costs within specific building applications where implementing fabric improvement measures (such as installation of internal wall thermal insulation) would necessitate associated internal room alterations, i.e. modifications to existing bathroom suites, kitchen units, internal doorways, etc.

- Additional costs associated with local area around the location of external heat pump units, i.e. landscaping, visual screening, etc.
- Decommissioning or safe disposal of previous heating system components beyond immediate boiler plant, i.e. redundant external oil or LPG storage tanks and pipework distribution, etc.
- Costs associated with any replacement flooring and floor coverings necessitated by a requirement to lift existing flooring.
- Costs associated with planning applications and/or Building Control applications were excluded.

Appendix B – Northern Ireland Electricity Networks Applications Process

The following application forms and processes are listed below:

- Low Carbon Technologies - Combined Installation Process Flow Chart. The flowchart applies to existing and new premises (domestic buildings only). For commercial buildings there doesn't appear to be any difference between the route-map for domestic and commercial buildings.
- Single Electric Vehicles and Heat Pumps - Installation Application Form. The form is for Electric Vehicle Charge Points (EVCP) or Heat Pumps (HP) being installed in existing premises with an existing Distribution Network Operator (DNO) electricity connection.
- Electric Vehicles and Heat Pumps - Multi install Application Form.

Data available online[101]: Connect a new home, business or property to our network | Northern Ireland Electricity Networks (nienetworks.co.uk)

It should be noted that:

- NIE Networks will never refuse a connection, however, works may be required to ensure the connection is fit for purpose.
- If the connection of a Heat Pump at a residential property would give a new maximum demand greater than 60 A and less than or equal to 80 A, then the installer must apply for a connection prior to installation by filling in the Notification Form mentioned below. NIE Networks will assess the supply capacity within 10 working days.

Apply to Connect

If the DNO is appointed to do all works then the 'Apply to Connect' process should be followed. This is also the case if the ICP cannot resolve certain issues such as:

- The MD calculations performed by the installer indicate that a property's MD is greater than the known supply capacity.
- There are safety concerns over the cut-out, cut-out fuse, or any other existing equipment.
- There is uncertainty over the supply capacity or the adequacy of the supply.
- It is certain that the connection requires an upgrade.
- There is a looped supply.
- It is an unmetered supply.

There may be other conditions for having to Apply to Connect as set out in the notes section of the aforementioned flow chart.

Connect & Notify

If an ICP is appointed to carry out the contestable works, they will submit a design and, once approved, complete quality assurance inspections as well as undertaking construction of the non-contestable works. On completion of the works, the ICP issues a signed Completion Certificate to enable adoption of the works by the DNO.

<u>Electric Vehicles and Heat Pumps Multi install Application Form v4.4, Energy Network Association</u>

This form is_for multiple pieces of equipment (including multiple pieces of equipment under one controller) or multiple premises (existing).

[101] Connect a new home, business or property to our network | Northern Ireland Electricity Networks

ENA Heat Pumps Database

The ENA has a database that can be utilised by installers to cross-reference their device(s) to determine whether they can ‘Connect & Notify’ to NIE Networks or should ‘Apply to Connect’. Installers and manufacturers which have devices which are not currently included in the database may send details of the device to the ENA for inclusion. The ENA will be updating this database in the future to a more digital platform where manufacturers and installers can input their Heat Pump information, to be verified by ENA Members.

The heat pumps database has been created to assist with the technical details associated with heat pumps, that are necessary for the connection process. The database[102] in the form of a spreadsheet can be found online at Energy Networks Association (ENA) website, an installer can use this database to cross-reference their device(s) to determine whether they can ‘Connect & Notify’ to NIE Networks or ‘Apply to Connect’[103].

[102] ENA website
[103] Connecting to the networks – Energy Networks Association (ENA).

Appendix C – Technical Assessment Process for Heat Pump System Grants: ROI.

This report[104] presents the requirements to which a homeowner must adhere to apply for a Heat Pump System grant in the Republic of Ireland (ROI) under the *Better Homes* scheme. It refers only to domestic properties. Part of this process is similar to the Green Homes Grant voucher scheme in England in 2020/21 as it requires MCS certified products and a PAS2030 qualified installer.

Outline of the Grant and the Technical Advisor

The installation of Heat Pump Systems is grant-aided by Sustainable Energy Authority of Ireland (SEAI) under the Better Energy Homes and Communities programmes. One of the requirements for a dwelling to qualify for a grant for Heat Pump Systems is that the energy performance of the dwelling fabric is suitable for Heat Pump System installation. This requirement is in line with SEAI's aim for installed Heat Pump Systems to be as efficient and effective as is feasible.

To make this possible, an independent Technical Advisor, who is registered with SEAI, is engaged by the homeowner as part of the application process. The Technical Advisor guides the homeowner on the energy performance of the dwelling, particularly on the suitability of the dwelling for a heat pump system based on the dwelling's heat loss. They also provide the homeowner with independent guidance on measures necessary to ensure that the dwelling fabric heat loss is lowered to an acceptable level for a heat pump system to perform effectively and efficiently.

Outline of the Requirements for Obtaining the Grant

Domestic heat pump heating systems are most efficient when they operate in a dwelling with low fabric and ventilation heat losses. This enables them to operate at lower space heating distribution temperatures and to meet most or all the space and water heat demand. Therefore, it is a prerequisite for the installation of a Heat Pump System funded by the Better Energy Homes programme for the dwelling to have a suitably low level of fabric and ventilation heat loss.

Heat Pump Systems will only be eligible for the Better Energy Homes Grant when installed in dwellings meeting the following condition: HLI $\leq$ 2W/K-m^2. An HLI ≤ 2.3 can be accepted where the following requirements are met:

- Maximum exposed wall U-value 0.37 W/m^2 K.
- Maximum roof U-value 0.16 W/m^2 K or 0.25 W/m^2 K where not accessible (e.g. flat roof or rafters).
- Maximum Window U value 2.8 W/m^2 K* (and double glazed).
- Maximum Adjusted Infiltration Rate of 0.5 ac/h.

*Note the Cost Optimal Window performance is 1.4 W/m^2 K, however a value of 2.8 W/m^2 K recognises that it may not be economically feasible to upgrade windows.

Where the HLI is between 2 and 2.3 W/k-m^2, the homeowner should be advised that the cost savings may not be significant, depending on the fuel and efficiency of the current heating system.

The full evidence base utilised for setting these targets has not been reviewed, although there are likely to be differences between ROI and NI, including in the building stock and costs / currency. Non-domestic buildings are not eligible for this grant.

The qualifications for a Retrofit Assessor and Retrofit Designer for Northern Ireland are similar to a Technical Advisor in ROI. Both PAS 2035 and PAS2030 guidance are applicable for Northern Ireland and are relevant to the Better Energy scheme.

The only substantive difference between the ROI scheme and potential in NI is the metric for measurement. In ROI they use HLI. Specifically, the Heat Pump System Grant is applicable to every domestic building that has HLI ≤ 2

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W/K-m^2 or ≤ 2.3 W/K-m^2 under certain circumstances RdSAP is the tool available for fabric efficiency in NI and uses a metric of W/m^2 for heating demand. There is a correlation between kWh/m^2 and HLI, but a conversion sum would be needed to take account of the efficiency of the existing heating plant.

This website gathers all the information that is relevant to contractors carrying out the works under the Better Energy Homes Scheme and to ensure that these works meet the required SEAI standards[105].

A summary of the information listed in this website is:

- Domestic Technical Standards and Specifications (DTSS) -The DTSS details the technical requirements for the SEAI residential Programmes. A Contractor carrying out works for these Programmes must have the minimum levels of competency and commit to supplying materials and equipment and to perform the works to the defined requirements.
- Better Energy Homes Contractor's Code of Practice - The Better Energy Homes Code of Practice sets out the programme-specific requirements on contractors in carrying out works supported by the Programme.
- Quality Assurance and Disciplinary Procedures (QADP) -The Quality Assurance and Disciplinary Procedures (QADP) document details the quality assurance procedures that are in place to govern the Better Energy programmes, including the reworks process. There is a link to an Inspector's checklist that helps to snag contractor’s own work.
- Additional Information for Contractors - This document contains additional technical information that is not covered in the Code of Practice and QADP. It includes revisions to the SEAI programme standards that must also be adhered to in conjunction with the Code of Practice and QADP documents.
- Desktop Audit Photographic Guidance - This document provides guidance on the photographic evidence required as part of a Desktop Audit to assist with the verification of the installation of works.
- Appeals - there is a form to be completed as part of the appeals process.

Technical Guidance and Safety Notices

This section is relevant and useful for the NI Heat Pump tool.

Firstly, the ‘Heat Pump Designer/Installer Sign Off Sheet’ has the following useful questions for the heat pump installation:

- Is the Heat Pump compliant with Ecodesign or Labelling Directive?
- Is the Heat Pump Listed on the Home Heating Appliance Register of Performance (HARP). This database is a product efficiency database for home heating appliances in Ireland?

The HARP database provides domestic BER assessors with information on the efficiency of heating appliances available in Ireland for use in DEAP. Product submissions to HARP include product test data, product identification documentation and HARP submission forms. The database has been in operation since 2006. It examines:

- Number of hours per day the Heat Pump has been designed to run.
- % main space heat provided by each heat pump based on system design. % for hot water.
- Temperature (°C) of the water leaving the heat pump for space heating. For hot water.
- Is there a backup space / water heater present to supplement heat pump.
- Outline type of backup space/water heater and associated fuel.
- Is the heat pump source pre-conditioned.
- Is the heat pump part of a group heating scheme.
- About heat emitter design:
    - Number of radiators present.
    - Number of fan coil units present.

[105] It is a prerequisite for the installation of a Heat Pump System funded by the Better Energy Homes programme for the dwelling to have a suitably low level of fabric and ventilation heat loss. The metric used to determine if the dwelling has sufficiently low fabric and ventilation heat loss is the Heat Loss Indicator (HLI). Heat Pump Systems will only be eligible for the Better Energy Homes Grant when installed in dwellings meeting the following condition: HLI < 2 W/Km^2.This is calculated by the DEAP software based on a DEAP assessment accurately reflecting the dwelling at the time of the Technical Assessment. Higher than 2 W/Km^2 is possible to receive a grant under certain circumstances, but it should always be <2.3 W/Km^2

- Is there warm air supply from the heat pump.
- Has a load/weather compensation been installed.
- Provide details of zone, temperature and time control installed.
- Temperature of water leaving the heat pump system while providing hot water (by heat pump only) based on certified data.
- Type of DHW store.
- Manufacturer of the installed DHW store.
- Model of the installed DHW store.
- Is there an integral immersion or electric element present capable of providing hot water.
- There are also several tabs for more inputs to the heat pump design. This consists of the 'heating design', 'radiator output conversion' and a BER Checklist. The last is provided on the next page.

The Ecodesign Technical data includes links to manufacturers' data, mainly around Energy Related Products Directive (ErP) ratings for the heat pumps themselves. A key input from Daikin regards the importance of the seasonal efficiency as being the more accurate representation of the energy a heat pump system is consuming throughout the year. Another input from Fujitsu highlighted the importance of controls. The manufacturers available in the list are: Daikin, Ecoforest, Fujitsu, Grant Aerona, Hitachi, Mitsubishi Electric, Panasonic, Thermia, Viessmann and Waterfurnace.

The Heat Pump Association of Ireland (HPAI) have published a technical document covering installation guidelines for heat pump systems. The guidelines cover how to size a system correctly (noting specific inputs such as internal room temperature and flow temperature etc), how a heat pump system works, outlining requirements at commissioning / handover, and maintenance of a heat pump system.

A further publication from the Heat Pump Association of Ireland is 'Room Heat Loss and Radiator Sizing Guidance'. In addition to information relating to heat loss and radiator selection this contains two links for Contractor's support regarding installation of heat pump systems. These include a technical bulletin with photos indicating what is considered a correct installation and what is not, along with a video explaining the publications.

BER + Heat Pump Grant Checklist

1.0 Designer/Installer sign-off sheet

1.1 Designer/Installer sign-off sheet has been completed and signed using one of the 3 methods. ☐
Note: If the heat pump is being grant aided, section 6 needs to be completed by the SEAI registered contractor

2.0 Heating Design Sheet contains:

2.1 Dwelling address of heat pump installation ☐

2.2 The design flow & return temperatures ☐

2.3 Where radiators / fan coil emitters are specified, the room heat loss (W), manufacturer, model/size, single heat emitter output [W], number of emitters, total heat emitters output [W], design room temp. (°C) and ΔT for heat output. ☐

2.4 Where underfloor heating is specified, the room (or area) heat loss [W], total heat emitter output [W] and UF output [W/m2]. ☐

2.5 Where an air system is specified, the room heat Loss [W], manufacturer, model, single heat emitter output [W], number of emitters, total heat emitters output [W], supply air temperature [°C] and air flow rate l/s. ☐

2.6 The total heat emitter output (W) is greater than total room heat loss (W) ☐

2.7 The HLI stated on the heating design sheet, or equivalent, is within a 10% tolerance of the total heat loss per m2 of dwelling, as calculated in DEAP. ☐
Where HLI DesignSheet is more than 10% larger than HLI DEAP, the BER Assessor must ask the Designer to confirm in writing that they followed the SR 50-4 standard for heat loss calculations and sizing, highlighting the risks of oversizing HP systems. If the Designer provides this confirmation then the non-default flow temperature can be used, as long as all other conditions are met. If the Designer does not provide this confirmation, then the default flow temperature must be used.

2.8 Heat pump output at design conditions based on test data & design flow temp. provided for DEAP assessment ☐

2.9 The name and contact details of the Designer/Installer ☐

3.0 Radiator Technical Data Sheets

3.1 For new radiators, the output of the radiators for the ΔT specified in the heating design sheet matches the manufacturer's stated output **and/or** ☐

3.2 For existing radiators being retained, the output of the radiators for the ΔT specified in the heating design sheet matches the guidance for existing radiators contained within *'Heat Emitter Supplement to the Domestic Heating Design Guide'* ☐

3.3 Where the ΔT_{design} specified in the heating design sheet differs from the ΔT quoted in the manufacturer's technical data, the tab "Radiator output conversion" must be filled out to demonstrate how heat outputs have been converted for ΔT_{design} ☐

4.0 Site Survey

4.1 Check that the type of heat emitter installed in each room matches the heat emitter type specified ☐

4.2 Check that the radiators as specified in the heating design sheet and as described in the radiator technical data sheet, match (approximately) those installed in the dwelling ☐

4.3 Check the air volume as specified in the heating design sheet meets the design specification or commissioning data sheet for the air system ☐

Notes

Methods for signing:
1. Hardcopy signed by Designer/Installer, or
2. Softcopy format with an electronic signature from Designer/Installer, or
3. Softcopy format accompanied by email from designer/installer confirming that the data in the sign off sheet is correct.

***PLEASE NOTE** - To support the input of a heat pump in DEAP, the following is required for HP compliant with Ecodesign/Energy Labelling Directive:*
1. Designer/installer sign-off sheet;
2. Technical documentation outlining declared test data in accordance with EN 14825 and EN 16147;
3. Where non-default flow temperatures are used to calculate the SPF of the HP, all items on this checklist must also be provided

In addition to the above, the Registered Contractor must provide the following to the homeowner for grant payment:
1. Signed-Off Declaration of Works;
2. Two hardcopies of the Designer/Installer sheet and Heating Design tab (no equivalent documents are accepted) and
3. Ecodesign datasheet for heat pump installed
4. The radiator heat output data must be verifiable through published datasheets. If this data is not widely available (e.g on internet), please submit the data source for the heat output.

For guidance on how to estimate the heat output of existing radiators at the correct ΔT, please refer to the following documents:
- SEAI BER Technical Bulletin;
- NSAI SR 50-1 Building services - Code of Practice - Part 1: Water based heating systems in dwellings;
- NSAI SR 50-4 Building services - Code of practice - Part 4: Domestic Heat Pump Systems;
- 'Heat emitter supplement to the Domestic Heating Design Guide' by the IDHEE;
- 'Domestic Heating Design Guide' by CIBSE.

The heating design sheet must reflect what is installed in the dwelling. If an assessor finds something different in the house, the Designer/Installer needs to update the heating design sheet to reflect what is installed. If this is not done, default flow temperatures must be used.

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