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Energy Innovation Needs Assessment: Heating and Buildings

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Authors

The 2025 Energy Innovation Needs Assessment: Heating and Buildings was commissioned by the Department for Energy Security & Net Zero (DESNZ) and delivered by a consortium led by the Carbon Trust, including Mott MacDonald, UCL and Pengwern Associates.

Carbon Trust was the lead technical author for the heating and buildings technology theme report.

Views expressed in this report are those of the authors and not necessarily those of the UK Government.

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Abbreviations

AAHP	Air-to-air heat pump
ASHP	Air source heat pump
AWHP	Air-to-water heat pump
AI	Artificial intelligence
CAPEX	Capital expenditure
CCC	Climate Change Committee
CCUS	Carbon capture, utilisation and storage
CERT	Carbon Emissions Reduction Target
CESP	Community Energy Savings Programme
DESNZ	Department for Energy Security and Net Zero
DSM	Demand side management
DSR	Demand side response
EaaS	Energy-as-a-Service
ECO	Energy Company Obligation
EEC	Energy Efficiency Commitment
EESoP	Energy Efficiency Standards of Performance
EINA	Energy Innovation Needs Assessment
EU	European Union
EV	Electric vehicle
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HaaS	Heat-as-a-Service
HD	High Diversification

HH	High Hydrogen
HPA	Heat Pump Association
HUG	Home Upgrade Grants
HVAC	Heating, ventilation and air conditioning
IoT	Internet of Things
LAD	Local Authority Delivery
LAEP	Local Area Energy Plan
LDES	Longer duration energy storage
LV	Low voltage
MC	Minimally Constrained
NAO	National Audit Office
NESO	National Energy System Operator
NVQ	National Vocational Qualification
O&M	Operation and maintenance
PCM	Phase change materials
PIR	Polyisocynurate
PLF	Property Linked Finance
PV	Photovoltaic
R&D	Research and development
SSHP	Solid state heat pumps
TES	Thermal Energy Storage
TRL	Technology Readiness Level
UCL	University College London
UHI	Urban Heat Island
WSHP	Water Source Heat Pump

Key findings

The Energy Innovation Needs Assessments (EINAs) have been developed and updated to identify key innovation needs across the UK's energy system, to provide an evidence base for the prioritisation of investment and support for clean energy innovation. This report summarises the analysis and findings from the EINAs across the heating and buildings technology theme, focusing on building insulation and heat pumps.

The deployment of insulation is expected to continue to increase, both globally and in the UK, driven by consumer demand for greater home efficiency, building standards, house building targets and government decarbonisation programmes. Key innovation needs remain aligned to those identified in the 2019 EINAs and include improved and guaranteed performance, advancements in modelling and testing, design for manufacture and assembly, low embodied carbon materials and skills and knowledge sharing. There is currently a greater need for innovation in the approaches for deploying existing insulation technology cost-effectively, at scale and to high standards, rather than an urgent need for further innovations in specific insulation technologies. Innovation is needed to ensure that existing insulation technologies can deliver carbon savings cost effectively as well as enhance a building's fire resistance and climate resilience, provide health, wellbeing and cost benefits to building occupants and deliver wider societal and economic benefits.

Heat pumps powered by low and ultimately zero emissions electricity are key to the Net Zero transition agenda in the UK and are expected to play a key role in becoming the primary means of decarbonising space and water heating. Despite becoming a more widely available and utilised technology, there is still a significant opportunity for innovation to further reduce costs and increase deployment. Efficiency of heat pumps could be increased, e.g. through improved refrigerants, components or operating settings, whilst better manufacturing practices could improve quality.

Energy system modelling to assess the potential impact of innovation in key net zero technologies was conducted using UK TIMES. Technologies were assessed at 3 levels of innovation (low, medium and high) and across three hypothetical scenarios: Minimally Constrained, High Hydrogen and High Diversification.1 The key results from EINAs system modelling suggests that:

- Roof insulation has limited innovation potential in terms of cost reduction. Floor insulation, while reducing costs across innovation levels, does not have higher deployment in any of the innovation levels (aside from their high innovation run in HD). These outcomes might reflect the low economic value of deploying these types of insulation, and that the model does not require houses to be highly insulated to use heat pumps. Innovation in wall insulation does play a role across the 3 scenarios, particularly at the higher level indicating that cost savings for insulation are primarily driven by innovation in wall insulation.

- Air source heat pumps (ASHP) are integral to achieving net zero across all innovation runs. Deployment of ASHPs reaches the assumed maximum feasible yearly installation level in most innovation runs, meaning that the technology is highly valuable to the energy system and is often used to the maximum extent the model is allowed to. As a result of the importance of ASHP in achieving net zero by 2050, cumulative cost savings in the High Diversification scenario at the high innovation level reach £110.8bn in 2050 compared to £67.8bn and £71.7bn in the High Hydrogen and Minimally Constrained scenarios respectively.
- Water source heat pumps (WSHP) have a more niche role to play in the energy system but are significantly impacted by innovation levels with a 2-fold deployment increase at the medium innovation level and a 3-fold increase at the high innovation level by 2050, compared to the all low Minimally Constrained case. This is also observed for High Hydrogen scenarios, where 5–8-fold increase is observed in their innovation runs. WSHPs are already widely deployed in the High Diversification all low innovation run, with further increases as cost reductions are assumed for these technologies. Cumulative cost savings at the high innovation level in the High Diversification level reaches £17.8 billion in 2050, whilst it reaches £8.7 billion in Minimally Constrained and £7.4 in the High Hydrogen scenario.

The key innovations to support the deployment and scale up of building fabric and heat pumps are outlined in Table 1.

Table 1: Innovation needs for the EINAs heating and building technologies

Innovation area	Description
Building insulation	Advancements in modelling and testing to enable increased data collection, analysis and sharing across all stages of building construction; improved design for manufacture and assembly for offsite/prefabricated construction and precision manufacturing for new builds and retrofits; improved and guaranteed performance of insulation materials with focus on improving specification, installation and maintenance processes.
Heat pumps - systems	Low global warming potential refrigerants that can allow high efficiencies at high temperatures (above 60°C); increased component efficiency and temperatures, e.g. new compressors and solid-state technologies
Heat pumps - Installation	Integration of plug-and-play hardware and software alongside easy-to-use modelling tools to design and specify systems; modularised systems, including pre-plumbed or integrated system elements such as hot water cylinders and buffer tanks into heat pump enclosures.

Heat pumps - Manufacturing	Integration of standardised or modular components and systems for mass production; automation and robotics to increase manufacturing capability; streamline supply chains; improving component quality; components to support a circular economy.
Heat networks	Innovate and reduce cost of Heat Interface Unit (HIU); develop tools to increase accuracy of peak demand and heat demand estimates; innovate to minimise household disruptions to enable faster installations. Innovation for Thermal Energy Storage (TES), integrated solutions in buildings to provide flexibility, and support access to balancing and flexibility.

Additionally, there are still significant non-technological innovation barriers that need to be overcome to accelerate the deployment of heat pumps, including financial support for customers, improved supply chains and a greater number of installers with the required skills. Three of the key market barriers to the scale up and deployment of these innovative technologies include:

- **Availability of consumer investment:** relative to incumbent gas boilers, upfront costs for heat pumps, enabling works and operational costs contribute to a challenging financial proposition for consumers.
- **Supply chain:** The UK currently has a limited domestic heat pump manufacturing sector, meeting just over 30% of UK demand. Additionally, global supply chain pressure on semiconductors, and high energy prices, are contributing to the limited UK supply chain.
- **Skills and training:** There is a limited number of active heat pump installers in the UK, and the existing market is characterised by small companies or sole traders. The heat pump workforce has been growing steadily, with around 9,000 individuals taking training in 2024[1], but the workforce will need to continue to grow to keep up with future demand.

Overall, the key results from the business opportunities calculator suggests the following potential business opportunities:

- Substantial GVA growth across all scenarios with a CAGR of between 7% and 8% between 2025 and 2050 with, depending on the scenario, GVA reaching between £5.2bn and £5.7bn by 2050 with medium innovation.
- Wall and floor insulation are only deployed at a large scale in the High Diversification scenario. In this scenario, the deployment of these technologies is expected to be almost exclusively conducted in the 10-year period between 2030 and 2040. This condensed deployment profile means that, during this period, there is an additional GVA contribution which averages at around £3.5bn per year from those technologies alone.

[1] Heat Pump Association (2025): Statistics - Heat Pumps

- There is a high level of variation in the amount of GVA supported between innovation levels for all three scenarios from 2040 onwards. In many years/scenarios, higher levels of innovation are associated with a higher GVA contribution. The main exception to this is in the High Diversification scenario, where the additional deployment of wall and floor insulation (which benefit from a significant reduction in cost as a result of innovation) leads to higher GVA results.
- Heat pump technologies, largely driven by ASHPs, make a significantly larger contribution to GVA in 2040 and 2050 than insulation technologies. In combination heat pump technologies account for 81% of total GVA in 2040 for those technologies studied, and 78% in 2050, in the Minimally Constrained and High Hydrogen scenarios. In the High Diversification scenario, heat pump technologies account for a lower share (40% in 2040 and 72% in 2050) as a result of the increased deployment of wall and floor insulation in this scenario.
- Supported total employment (direct and indirect jobs) for those technologies studied reaches between 170,000 and 183,000 jobs by 2050, which implies a growth rate of roughly 8% in all of the modelled scenarios. There are roughly 7% more jobs supported by 2050 in the High Diversification scenario relative to the other two scenarios reflecting the higher wall and floor insulation deployment in that scenario.
- Extra wall and floor insulation deployment in the High Diversification scenario leads to an additional 146,000 jobs in wall and floor insulation in 2040 relative to the Minimally Constrained and High Hydrogen scenarios.
- Across scenarios and across the time horizon, around 50% of supported jobs are direct jobs.
- The domestic market is expected to support the majority of jobs in the sector with 75-89% of jobs supported by domestic deployment across the time horizon and across scenarios. The export market is expected to become more important over time, supporting 28,000 jobs in 2040 and as many as 41,000 by 2050.
- ASHPs represent the most promising export opportunity, contributing 35% of export driven GVA by 2050. Collectively, insulation technologies make up 60% of export driven GVA in 2050; 31% from wall insulation, 15% from floor insulation and 13% from roof insulation.
- As the sector matures and the ratio of new capacity to existing capacity falls, there is a shift from GVA and jobs being driven by construction activity to increasingly being driven by operations and maintenance.
- There is an employment profile that, by 2050, is predominantly supporting skilled construction and building trades which are required to install and maintain the insulation and heat pump technologies. There second most prevalent occupation type are high skilled science, research and engineering and technology professional occupations.

Introduction

The Energy Innovation Needs Assessments

Achieving the UK's ambitious Net Zero target requires the accelerated scale up and deployment of innovative clean energy technologies. The UK Government has a central role to play in supporting research, development and deployment of these innovations to achieve global and national climate objectives. The decisions made now on the prioritisation and investment in crucial clean energy technologies will be pivotal in enabling progress in the coming years and decades.

The Energy Innovation Needs Assessments (EINAs) have been developed and updated to identify key innovation needs across the UK's energy system, to provide an evidence base for the prioritisation of investment and support for clean energy innovation. The 2025 publications reflect an update on the 2019 exercise, accounting for the significant changes and progress both in the clean energy sector and wider economy. To complement and build on the UK's Net Zero Research and Innovation Framework, the updated EINAs will inform key decisions on clean energy innovation funding, by providing a structured evidence base, comparable across different technologies, which quantifies and assesses the role and scale of opportunities and considers the wider factors that may impact deployment and scale up.

The methodology followed is detailed in the EINAs Methodology report and is summarised below.

The EINAs technologies were decided through a prioritisation exercise, taking into account insights from key sector experts and prioritising against key DESNZ criteria. An initial longlist of technologies for analysis was put together based on:

- Previously published global and national scenarios (including the 2019 EINAs)
- DESNZ priorities
- Insights from DESNZ engagement activities
- Input from technical experts

This longlist was then assessed and prioritised to inform a shortlist of EINAs technologies, which were then taken forward for analysis including:

- An assessment of each technology's innovation needs, costs and barriers to deployment.
- Modelling, using the UKTIMES and HighRES models, to assess the impact of different levels innovation in these technologies on the UK's energy system in hypothetical Net Zero scenarios, including on system cost, capacity and energy security.
- Business opportunities analysis, including Gross Value Added (GVA) and employment, of the deployment of the technologies across scenarios and innovation levels.

This report summarises the findings across the heat and buildings technology theme.

The 2025 EINAs publications have been commissioned by DESNZ and produced by a consortium led by Carbon Trust, including Mott MacDonald, UCL and Pengwern Associates. Carbon Trust and Mott MacDonald was the joint lead technical authors for the heating and buildings technology theme report.

Scope and limitations of the EINAs:

The EINAs project is a research exercise to evaluate the potential impact of technological innovations on the UK energy system and Net Zero targets, and help inform decisions on clean energy innovation.

A number of technologies were included as part of the prioritisation but were not included in the systems modelling due to limitations of the models used for the EINAs, data availability and resource constraints. The three hypothetical scenarios developed to represent potential routes to Net Zero were selected due to their differing constraints which provide a more diverse set of outputs and insights.

The technologies and scenarios selected do not represent UK Government policy.

Heating and buildings technology theme

Decarbonising heat in buildings can be achieved by transitioning to systems driven by fuels or energy sources that are or have the potential to be zero carbon, such as electricity, hydrogen or renewable energy such as solar energy. This transition needs however to be undertaken holistically and in conjunction with energy efficiency measures, to limit the impact on the consumer operational energy costs and minimise the additional energy demand required as part of a switch net zero carbon energy such as electricity.[2]

A shortlisting and prioritisation exercise was conducted to determine the heating and buildings technologies to be modelled and studied in this update of the EINAs. This followed a framework which considered the following factors important to DESNZ:

- **Known net zero priority:** Technologies where there is a clear government direction or expert consensus.
- **Energy security:** Technologies necessary for system resilience (grid/import shocks).
- **UK relevance:** Technologies suitable for UK specific circumstances, and where the UK is likely to have an impact.
- **Technology Readiness Level (TRL) relevance:** Technologies close to commercialisation or likely to be commercially viable by 2040.

The technologies included as part of the EINAs are detailed in Table 2.

[2] NESO (2024) Future Energy Scenarios: ESO Pathways to Net Zero

Table 2: EINAs technologies in the heating and buildings technology theme

Technology	Description
Insulation (for roofs, walls and floors)	Insulation is a known net zero priority. Approximately 70% of heat loss from an uninsulated house occurs through the roof, wall and floors.[3] Correctly specified and installed building fabric insulation improves the thermal performance of these building elements, reducing the rate of heat transfer and therefore reducing energy demand for heating and cooling. Ventilation must be considered alongside insulation in buildings to avoid unintended consequences such as damp, mould and decay. There are various forms of insulation available for walls, roofs and floors. There is a mature market for conventional forms of insulation including mineral wool, fiberglass, cellulose / wood fibre and plastic-based (e.g. polystyrene, polyurethane etc.) rigid boards, cavity beads and spray foam[4]. Newer, innovative alternatives include high performance 'aerogel'[5] as well as materials with lower environmental impact such as sheep's wool[6], cork[7], hemp[8], grass[9], mycelium[10] and recycled newspaper[11]. UK building regulations require minimum levels of thermal performance for roofs, walls and floors as well as other elements of the building envelope[12]. Insulation materials are essential for meeting these standards. Building age, construction type and geographical location must all be considered when selecting insulation materials for new build and retrofit projects – there is no single insulation solution for the UK's heterogenous building stock and varied climate. E.g. retrofit for traditional (pre-1919) solid walled buildings is likely to require moisture permeable ('breathable'), non-plastic-based insulation materials[13]; cavity wall insulation should not be installed in exposed locations with wind driven rain or in areas at risk of flooding etc[14]. Given the maturity of insulation technology and other contextual changes, evidence suggests there is currently a greater need for

[3] Wealden District Council (Accessed: 2025) Heat loss and insulation
[4] Energy Saving Trust (Accessed: 2025) Measures to help reduce home heat loss
[5] Proctor Group (Accessed: 2025) Spacetherm® - Ultra Thin Aerogel Insulation for Retrofit & Newbuild - A. Proctor Group
[6] British Wool (Accessed: 2025) Wool Insulation
[7] Sierra-Pérez, J. et al. (2018) The use of forest-based materials for the efficient energy of cities: Environmental and economic implications of cork as insulation material
[8] Bio-based Prefab Modular Building System | UKGBC
[9] UK GBC (Accessed: 2025) Insulation boards made from meadow grass
[10] UK GBC (Accessed: 2025) Mycelium insulation
[11] Warmcel® (Accessed: 2025) Warmcel Cellulose Fibre Insulation, Insulation for Timber Frame.
[12] UK Government (2023) Conservation of fuel and power: Approved Document L
[13] Historic England (2015) Planning responsible retrofit of traditional buildings
[14] Energy Saving Trust (Accessed: 2015) Cavity wall insulation

Technology	Description
	innovation in the approaches for deploying existing insulation technologies cost-effectively, at scale and to high quality standards, rather than an urgent need for further innovations in specific insulation technologies.
Air Source Heat Pump (ASHP)	An ASHP moves thermal energy from the outside air to water (air-to-water) or air (air-to-air) by using electricity to drive a vapor compression refrigeration cycle. The heated water or air is used to heat a space or provide domestic hot water. ASHPs can also be used in reverse to move energy from inside a building to outside thus provide cooling in buildings. ASHPs typically use external air as a heat source but can also recover heat from exhaust air leaving a home or a different waste heat source. These are generally considered a separate application of ASHPs and are referred to as exhaust air heat pumps. ASHPs represent 82.6% of heat pump units sold in the UK in 2024.[15] They are a mature technology used in both the domestic and non-domestic sectors. The total number domestic and non-domestic ASHPs installations through government supported schemes since 2018 were 157,770 as of Q2 2025.[16] While globally air-to-air units represent the majority of the market,[17] in the UK almost all of the ASHPs units sold in the domestic heating market are air-to-water heat pumps and will be considered as the main ASHP technology within this report. Low temperature air-to-water monobloc (single unit) systems represent 69% of the total heat pump market in the UK. There are at least 33 manufacturers supplying ASHPs in the UK, with Mitsubishi Electric, Vaillant, Daikin and Samsung accounting for nearly two-thirds of total annual UK sales through imports and local supply in 2024, with the rest being distributed amongst other manufacturers. The main companies manufacturing air source heat pumps in the UK in 2024 were Mitsubishi Electric, Vaillant, Ideal and Octopus Energy accounting for total market share of 34%. For ground source heat pumps, Kensa Heat Pumps are the market leader and manufacture domestically.[18] A Heat Pump Association (HPA) report on the capability of hydronic heat pump manufacturers in the UK showed that since 2019 the UK ASHP

[15] HPA (2025) Heat Pump Supply Chain readiness to deliver Net Zero Homes
[16] DESNZ (June 2025) Heat_pump_deployment_quarterly_statistics_United_Kingdom_2025_Q2.xlsx
[17] DESNZ (2020) Heat pump manufacturing supply chain research project report
[18] BSRIA (2025) World Heat Pump Market 2025

Technology	Description
	market has developed further with an almost 4-fold increase in air-to-water monobloc and split units annual sales units from 2019 to 2024. [19], [20]
Water Source Heat Pump (WSHP)	A WSHP uses the heat energy from a water source to provide heating and hot water. It extracts energy from water and turns it into heat, even when the water temperature is lower than the air temperature needed in a house. The two main WSHP designs are closed and open loop systems.[21] Heat can be extracted from different water sources such as large surface water bodies (e.g. lakes, the sea or rivers) or waste heat from domestic, commercial (such as data centres) or industrial processes. This report focuses predominately on the former group of WSHPs. WSHPs and GSHPs represent 3.3% of heat pump units sold in the UK in 2024.[22] WSHPs are a mature technology used in the UK in both the domestic and non-domestic sectors. The total number of domestic and non-domestic WSHP and GSHP installations through government-supported schemes was 10,642 as of Q4 2024.[23] The focus of the EINA is on WSHPs linked to heat networks, which provide the opportunity to connect centralised heating systems such as WSHPs to a larger scale area and customer types.
Ground Source Heat Pump (GSHP)	A GSHP (also known as a ground-to-water heat pump) transfers heat from the ground to water, which is used to heat a space and provide hot water. Thermal transfer fluid (TTF), a mixture of water and antifreeze, flows around a loop of pipe buried underground. Heat from the ground is absorbed into the TTF, which then passes through a heat exchanger into the heat pump. This raises the temperature of the fluid and then transfers that heat to water.[24] In GSHP systems, the actual heat pump unit is a water-to-water heat pump designed to operate at the correct temperatures and connected to the appropriate open or closed loop collectors.

[19] HPA (2025) Heat Pump supply Chain Readiness to deliver Net Zero Homes
[20] HM Government (2020) The Ten Point Plan for a Green Industrial Revolution
[21] Energy Saving Trust (2024) A guide to water source heat pumps
[22]HPA (2025) Heat Pump Supply Chain readiness to deliver Net Zero Homes
[23] DESNZ (Dec 2024) Heat_pump_deployment_quarterly_statistics_United_Kingdom_2024_Q4_Table_1.2
[24] Energy Saving Trust (2024) Ground source heat pumps

Technology	Description
	WSHPs and GSHPs represent 3.3% of heat pump units sold in the UK in 2024.[25] GSHPs are a mature technology used in the UK in both the domestic and non-domestic sectors. The total number of government-supported domestic and non-domestic WSHP and GSHP installations through DESNZ-led schemes were 10,876 in Q2 2025.[26] Similarly to WSHPs, the focus of the EINA is on GSHPs linked to heat networks, which provide the opportunity to connect centralised heating systems such as GSHPs to a larger scale area and customer types. While not currently widely deployed, this solution has been part of ongoing investment opportunities with completed and proposed projects across both England and Wales. [27] There are at least 17 manufacturers in the GSHP market, but only Kensa (41% of market share) manufactures its systems in the UK. Kensa and NIBE accounted for approximately two-thirds of the market in the UK as of 2019.[28]

Exclusions from the EINAs include:

- Other forms of insulation: Roof, wall and floor insulation has been prioritised over other insulation types, including glazing insulation, draught proofing, building services insulation and foundations, as the majority of heat loss from homes occurs through these elements of the building fabric. The system modelling is also limited to focusing on these three types of insulation.
- Air-to-air heat pumps were excluded from the analysis as the UK TIMES model does not currently represent residential cooling demands, so does not value air-to-air heat pumps.
- Cooling systems are primarily electricity driven and while requiring efficiency improvements, they do not require the same decarbonisation effort as heating.
- Other low and zero carbon heating technologies such as direct electric, solar thermal, hydrogen boilers, or hybrid systems were not prioritised.
- Heat networks are considered as a distribution system for large air, water and ground source heat pumps, while acknowledging that these could use other heat or cooling generation systems as well. They are not covered by the system model but some qualitative information is provided in the report.

[25]HPA (2025) Heat Pump Supply Chain readiness to deliver Net Zero Homes
[26] DESNZ (Dec 2024) Heat_pump_deployment_quarterly_statistics_United_Kingdom_2025_Q2.ods
[27] DESNZ (2024) Heat Networks pipeline: Q3 2024
[28] DESNZ (2020) Heat pump manufacturing supply chain research project report

- The focus on the 2025 EINAs is for heat pump technologies in domestic settings. Non-domestic applications are referenced in the innovation needs mapping, but were not possible to include in the EINAs systems modelling and business opportunities analysis due to limitations in the UK TIMES model at the time of analysis.
- A number of technologies were excluded from the analysis due to methodological challenges and data availability. These include: shading, building control (demand side management), thermal storage – PCM, and air tightness/domestic and mechanical ventilation and heat recovery.

Heating, buildings and the energy system

The heating and buildings landscape in the UK

Contribution to UK greenhouse gas emissions: Emissions from residential buildings accounted for approximately 14% of UK greenhouse gas emissions in 2024,[29] primarily from fuel combustion for heating. While moving to low-carbon heating such as heat pumps or heat networks will drive the largest emissions reductions, insulation is key to reducing overall energy demand in individual buildings as well as across the wider energy system and is necessary to reach the UK's decarbonisation targets.[30] [31] [32]

Insulation

Building insulation globally and in the UK: Uptake and quality of building insulation varies significantly around the world. The UK has the highest rates of building heat loss in Western Europe, in part due to the age of its building stock.[33,34] Most of the UK's buildings are more than 60 years old, pre-dating regulations for insulation and thermal performance, with 1 in 5 homes over 100 years old.[35] Approximately 80% of the UK's existing buildings are expected to still be in use by 2050, with the majority needing retrofit measures to meet decarbonisation standards.[36]

Current deployment of building insulation: As of 2022, there were 29.6[37] million dwellings in Great Britain (GB). The share of homes insulated with cavity wall, solid wall, and loft insulation is outlined below.[38] Statistics for floor insulation and insulation in non-domestic buildings are not readily available.

- 21.4 million homes have cavity walls and of these 71% (15.2m) have cavity wall insulation.
- 8.76 million homes have solid walls and of these 10% (876,000) have solid wall insulation.
- 26.1 million homes have a loft and of these 67% (17.5m) have loft insulation with >125mm thickness. Around 1.3m homes have no loft insulation, and an additional 6.6m homes have some insulation of less than 125mm thickness[39], likely to be around 100mm in most cases.

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[29] DESNZ (2025) Provisional UK greenhouse gas emissions statistics 2024 - GOV.UK
[30] CCC (2020) The Sixth Carbon Budget: Buildings
[31] NESO (2024) Future Energy Scenarios: ESO Pathways to Net Zero
[32] CCC (2020) Development of trajectories for residential heat decarbonisation to inform the Sixth Carbon Budget
[33] Tado (2020) UK homes losing heat up to three times faster than European neighbours
[34] Grantham Institute (2022) Decarbonising Buildings: Insights from across Europe
[35] UK Government (2024) English Housing Survey data on energy performance, heating and insulation
[36] Energy Savings Trust (2021) Retrofitting the UK's housing stock to reach net zero
[37] ONS (2024) Dwelling stock by tenure, UK
[38] DESNZ (2025) Household Energy Efficiency Statistical Release
[39] DESNZ (2025) Household Energy Efficiency Statistics, headline release March 2025

There are regional differences in insulation deployment across England, Scotland, and Wales[38]. Scotland has a higher share of insulated homes compared to England and Wales across all three insulation types:

- 81% of homes with cavity walls compared to GB average of 71%.
- 86% of homes with a loft insulated with at least 125mm of loft insulation, compared to GB average of 67%.
- 23% of homes with solid walls insulated compared to GB average of 10%.

Compared to England, Wales has a higher share of cavity wall insulation, similar levels of loft insulation, but lower levels of solid wall insulation for the associated home types.

Current measures to facilitate uptake: Wide-ranging measures have been introduced to increase the pace, scale and quality of the deployment of building insulation in the UK over recent decades. Some examples of relevant interventions include (but are not limited to):

Legislation, policy and strategy:

- EU Energy Performance of Buildings Directive[40] - this legislation came into force in 2003, introducing the requirement for buildings being sold or let to have an Energy Performance Certificate.
- Heat and Buildings Strategy[41] - the 2021 UK Government strategy setting out the transition to high-efficiency, low-carbon buildings.
- Warm Homes Plan[42] - the 2024 Labour Government's plan to lift 1 million households out of fuel poverty and increase energy efficiency standards for rental properties.

Building regulations and standards:

- Parts L[43] and F[44] of the Building Regulations have set minimum insulation standards for new build homes and retrofit and have driven energy efficiency improvements.
- Future Homes and Buildings Standard:[45] the proposed new standard does not currently require an uplift to insulation requirements compared to existing standards.
- PAS 2030: Installation of energy efficiency measures in existing dwellings[46] and PAS 2035: 2023: Retrofitting dwellings for improved energy efficiency[47] came into effect in 2025, providing updates to the existing technical guidance on best practice retrofit (PAS 2030 and PAS 2035:2019).

[40] European Commission (Accessed: 2025) Energy Performance of Buildings Directive
[41] HM Government (2021) Heat and Buildings Strategy
[42] HM Government (2024) Home upgrade revolution as renters set for warmer homes and cheaper bills
[43] HM Government (2023) Conservation of fuel and power: Approved Document L
[44] HM Government (2022) Ventilation: Approved Document F
[45] HM Government (2024) The Future Homes and Buildings Standards: 2023 consultation
[46] DESNZ (2023) PAS 2030:2023 Installation of energy efficiency measures in existing dwellings - Specification
[47] DESNZ (2023) Retrofitting dwellings for improved energy efficiency - Specification and guidance

- Minimum Energy Efficiency Standards[48]: new proposals for private and social rented homes to meet EPC C by 2030.

Government support schemes and grants incentivising building retrofits or fuel poverty alleviation via insulation and other interventions e.g. Arbed[49], Great British Insulation Scheme[50], Green Homes Finance Accelerator[51], Home Energy Efficiency Programmes for Scotland[52], Home Upgrade Grants (HUG)[53], Local Authority Delivery (LAD)[54], NEST[55], Public Sector Decarbonisation Scheme[56], Social Housing Decarbonisation Fund[57], The Green Deal[58], Warm Homes: Local Grant[59] etc.

Cross sector trials: focusing on health, wellbeing or social aspects of retrofit e.g. Gentoo Housing Association, Bangor University and two Clinical Commissioning Groups' 'Boiler on Prescription' scheme;[60] the Energy Catalyst, the NHS and Severn Wye Energy Agency's Warm Home Prescription programme[61] and London School of Economics, Rockwool and ECD Architects review of social implications of retrofit at Wilmcote House.[62]

Private sector research and development: there have been advances in insulation technology and in approaches for designing, installing and testing insulation. Technological advances include high performance materials[63], insulation made from sustainable sources or industrial waste,[64,65] modular insulation[66] and offside manufacturing.[67] Digital tools to aid design, robotics to aid installation and methods for testing the in-situ performance of insulation systems have also been developed[68].

Regional and local area energy planning: area-wide energy modelling and planning methodologies have been developed and are evolving to identify and locate interventions for transitioning local energy systems to Net Zero, including identifying clusters of building insulation opportunities and estimating the associated levels of investment needed.[69][70]

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48 HM Government (2024) Home upgrade revolution as renters set for warmer homes and cheaper bills
49 Miller, N; Bajjada, T; Greaves, C; Oliver, D; (2022) Evaluation of Arbed 3 Final Evaluation Report.
50 HM Government (Accessed: 2025) Apply for support from the Great British Insulation Scheme
51 DESNZ (Accessed: 2025) Green Home Finance Accelerator
52 Scottish Government (Accessed: 2025) Home energy and fuel poverty
53 DESNZ (2024) Home Upgrade Grant: Phase 2 delivery guidance for local authorities
54 HM Government (2024) Summary of the Green Homes Grant Local Authority Delivery (LAD) and Home Upgrade Grant (HUG) statistics
55 Welsh Government (Accessed: 2025) Nest Warm Homes Programme
56 HM Government (2025) Public Sector Decarbonisation Scheme
57 DESNZ (2024) Summary of the Social Housing Decarbonisation Fund statistics
58 HM Government (Accessed: 2025) Green Deal: Energy saving for your home
59 DESNZ (2024) Warm Homes: Local Grant guidance
60 Burns, P., Coxon, J., (2016) Boiler on prescription trial: Closing report
61 Energy Systems Catapult (2022) Warm Home Prescription®
62 Rockwool (Accessed: 2025) ROCKWOOL raises standard of living at Wilmcote House, Case Study
63 ArchiScene (Accessed: 2024) Revolutionizing Energy Efficiency In Construction With Advanced Materials
64 British Wool (Accessed: 2025) Wool Insulation
65 UK GBC (Accessed: 2025) Mycelium insulation
66 Matilda's Planet (Accessed: 2025) Insulation Stop Mould and Cold
67 Rockwool Group (Accessed: 2025) Insulation for Offsite Building Construction
68 UK GBC (2023) Trends in Sustainable Solutions in the Built Environment 2023
69 Energy Systems Catapult (Accessed: 2025) Local Area Energy Plans
70 Ofgem (2024) Regional Energy Strategic Plan policy framework consultation

Skills and training: initiatives to develop the insulation workforce and supply chain e.g. the creation of the Retrofit Coordinator and Retrofit Assessor qualifications[71]; the Welsh Government's Net Zero Skills Action Plan[72] and funded 'Green Personal Learning Accounts'[73]; the establishment of The National Retrofit Hub[74] and The Retrofit Academy[75] membership organisation.

The 2024 UK Government Statistical Release on Household Energy Efficiency estimates that '7.8 million major professional insulation measures (cavity wall, loft and solid wall) have been installed through ECO and other government supported domestic energy efficiency schemes since 2009' (Figure 1).[76]

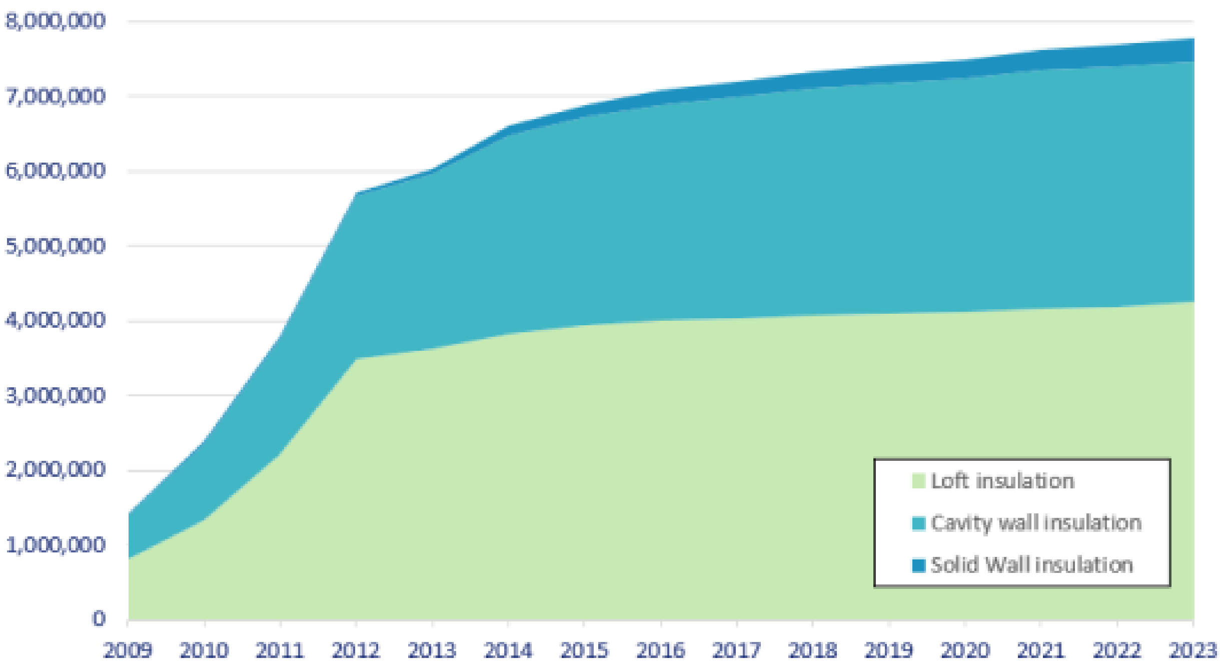

Figure 1: Cumulative professional insulation measures installed through Government energy efficiency schemes 2009-2023

Interactions with the wider energy system

Energy efficiency measures, such as building insulation, reduce the overall demand for energy which benefits the wider energy system since less energy generation is needed to meet demand. Additionally, better insulated buildings can help to improve energy system flexibility and reduce peak demand. More efficient buildings can retain heat for longer and therefore are more able to shift heating patterns away from peak times. Reducing and shifting energy

[71] National Energy Foundation (2024) An introduction to retrofit coordinators, retrofit assessors and what they do
[72] Welsh Government (Accessed: 2025) Net zero skills in Wales
[73] Welsh Government (2024) Green personal learning accounts (PLAs): approved courses
[74] National Retrofit Hub (Accessed: 2025) National Retrofit Hub
[75] Retrofit Academy (Accessed: 2025) Retrofit Academy
[76] DESNZ (2024) Household Energy Efficiency

demand are both critical for decarbonisation efforts. Each of the 2024 Future Energy Scenarios for the UK include insulation measures.[77]

Heat pumps

Heat pumps are used globally in both the domestic and non-domestic markets; the number of heat pumps installed in buildings globally would be required to rise from 180 million units in 2020 to 600 million units in 2050 to meet the IEA Net Zero Emissions Scenario by 2050.[78]

The global markets with the biggest heat pump share are China (32%), EU (25%), US (24%) and Japan (6%), together accounting for a total of around 88% of global heat pump sales in 2023.[79] The EHPA European Heat Pump Market and Statistics Report for the same year, which includes air-to-air heat pumps as part of ASHPs, reported that the UK had approximately 60,000 heat pump sales in 2023.[80] As a market comparison between the European and UK in 2023, the top three countries in Europe in terms of annual sales are France, Germany and Italy with 720,000, 437,000 and 378,000 units respectively. The annual sales across the 21 European countries[81] amounted to over 3,000,000 for all heat pump types in 2023.[82]

In terms of global sales trends, after two consecutive years of growth (16.5% growth in 2021 and 12% growth in 2022) fuelled by the energy crisis, the sales of heat pumps decreased by 3% in 2023 from a sales capacity of 111 GW to 108 GW. The decrease in growth rate is likely reflective of factors such as high interest rates and inflation, as heat pumps represent a large and price sensitive investment for household.[83] Overall, the EU market sales declined by 23% in 2024 especially Belgium and Germany due to changes in government support schemes, slow economy and the low price of subsidised gas.[84] Within the countries reported by the EHPA heat pump market sales report, the UK was the only country to experience growth with a 38,000 units increase in 2024 from 2023 heat pump sales numbers.[85]

The sales numbers of heat pumps (including air-to-air systems) across different countries are reflected in the respective number of installed units. In the EU, France has the largest number of units installed (approximately 6 million), followed by Italy and Sweden (approximately 4.1 and 2.5 million respectively). The number of heat pump units installed in the UK is just 7% of that in France.[86]

Significant and sustained growth in the level of overall heat pump deployment will be needed moving into the 2030s. Increased deployment will have to be supported by innovation across

[77] NESO (2024) Future Energy Scenarios: ESO Pathways to Net Zero
[78] IEA (2022) Technology and innovation pathways for zero-carbon-ready buildings by 2030
[79] IEA (2024) Clean Energy Market Monitor
[80] EHPA (2025) European Heat Pump Market and Statistics Report 2024
[81] Countries: FL, NL, DE, UK, FR, PL, AT, BE, DK, IT, NO, PT, SE
[82] EHPA (2025) European Heat Pump Market and Statistics Report 2024
[83] IEA (2024) Clean Energy Market Monitor
[84] EHPA (2025) European Heat Pump Market and Statistics Report 2024
[85] EHPA (2025) Pump it down
[86] EHPA (2024) European Heat Pump Market and Statistics Report 2024

multiple sectors, covering solutions for the development of the supply chain, new financial offerings and to limit the impact on the Low Voltage (LV) network.

Future deployment of technologies in heating and buildings

Heat pumps

Heat pumps have been acknowledged to have an important role to play in the net-zero transition, especially in decarbonising heat in the built environment. The IEA has estimated that for all governments to meet their announced energy and climate related commitments in time, the heat capacity of heat pumps will need to increase globally from 1000 GW in 2021 to 2600 GW in 2030, increasing the share in heating buildings from 10% to nearly 20%.[87]

The CCC's CB7 Balanced Pathway Scenario estimates approximately half of UK homes being heated by heat pumps.[88] The NESO Pathways to Net Zero of the Future Energy Scenarios (FES) 2025 suggest a stock of approximately 21 to 24 million heat pumps by 2050.[89]

In the context of the wider UK energy system, heat pump deployment is expected to have an impact on electricity demand, which can be in part addressed through innovation solutions.

A direct consequence of an increased deployment of heat pumps in the UK, and particularly a rapid increase, is the shift of energy demand from gas to electricity. Although heat pumps are more efficient at providing heating compared to gas boilers, they also increase overall electricity demand on the grid, especially during peak times. Depending on a range of factors such as the existing network headroom, the time of use and the level of heat pumps penetration and the level of demand from electrical vehicles (EV), the existing low voltage (LV) network capacity will need to be upgraded where it is not fully equipped to handle the additional demand, and additional electricity generation capacity will be required.[90]

Currently in the UK heat pumps have a very low penetration, with issues arising in areas where there is very limited transformer headroom on the LV network. Evidence suggests that against a sharp increase in peak loads, LV network reinforcements and upgrades with the associated costs are expected, but that these impacts can be mitigated if this process is actively managed.[91, 92]

Innovation can play a key role in limiting the impact of heat pump deployment on the LV network. Such solutions can be implemented on both the network and consumer side, such as use of energy storage to shift demand, improved heat pump efficiency in use, and consumer

87 IEA (2022) The Future of Heat Pumps
88 Climate Change Committee (2025) The Seventh Carbon Budget - Climate Change Committee
89 NESO (2025) Future Energy Scenarios 2025: Pathways to Net Zero
90 Watson, S. D., (2023) Predicting future GB heat pump electricity demand
91 DESNZ (2021) Heat Pump Ready Programme: background on innovation needs
92 DESNZ (2022) Low Voltage Network Capacity Study Phase 1 Report – Qualitative Assessment of Non-Conventional Solutions

led flexibility.[93] Consumer led flexibility includes, for example, well-sized and controlled behind-the-meter electrical or thermal energy storage, including building thermal mass. When used in conjunction with heat pumps, consumer led flex can help to avoid using electricity at peak times for the grid, alleviating the network loading. Used in conjunction with time-of-use tariffs, this solution can lead to lower costs for consumers. Demand side response (DSR) is a similar but more complex approach which can also benefit from integration with other technologies such as batteries, EVs or PV panels. DSR is defined more by direct load control or directly contracting flexibility from consumers where heat pump output is modulated directly during times of high network loading.[94]

There are currently a wide range of pilot projects in the UK that look to understand how domestic flexibility (shifting times of energy use) can be used to balance the supply and demand of the electricity grid and limit the impact on the wider energy system.[95]

A higher development rate of such innovative solutions can lead to overall lower costs for consumers and for the energy systems as a whole by reducing peak generation requirements, as well as the amount of LV network reinforcements and upgrades required.
Insulation

Potential future deployment of building insulation in the UK

The deployment of insulation is expected to continue to increase, both globally and in the UK, driven by consumer demand for greater home efficiency, building standards, house building targets and government decarbonisation programmes. By 2030, the European insulation market is projected to reach £24.5 billion (2023 market size was estimated at £13 billion) with a compound annual growth rate (CAGR) of 6.8%.[96]

The UK is a mature market for insulation which was progressing well with insulation retrofits in the late 2000s, however installations have stalled since 2012. This is in part due to a decline in government support schemes for building insulation along with fewer opportunities for installing the lowest cost, easiest to install measures e.g. insulating accessible lofts.[97]

According to the Climate Change Committee (CCC) Carbon Budget 7 publication (CB7), 5.5 million UK homes are recommended to have large energy efficiency measures (cavity wall, solid wall, loft, and floor insulation) by 2040.[98]

Additionally, the Government is aiming for 1.5m new homes to be built in 5 years (from 2024 to 2029).[99] All new homes in the UK will require insulation to meet building regulations.

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[93] DESNZ (2022) Low Voltage Network Capacity Study Phase 1 Report – Qualitative Assessment of Non-Conventional Solutions
[94] DESNZ (2022) Low voltage network capacity study
[95] NESO (Accessed: 2025) Crowdflex
[96] Greenmatch (2024) Global Insulation Statistics: 2024 Key Trends and Innovations
[97] House of Lords Library (2020) Home insulation and the net zero target
[98] Climate Change Committee (2025) The Seventh Carbon Budget - Climate Change Committee
[99] HM Government (2024) Housing targets increased to get Britain building again .

Trends for future building insulation deployment

In addition to energy and carbon reduction targets, other drivers for deploying insulation have become more prominent since the 2019 Energy Innovation Needs Assessment on building fabric was published.[100] These drivers – addressing fire safety, damp and mould, fuel poverty and the cost-of-living crisis, remediating failed insulation schemes and climate adaptation – all emphasise the need for greater focus on improving the quality of insulation installations (see ‘Insulation’ section).

Another recent shift in the sector is towards a more pragmatic approach to making buildings ‘heat pump ready’, instead of requiring exemplar standards of insulation in new builds and retrofit. Improving building insulation is a key enabler for the transition to low carbon heating. Emerging evidence suggests that ‘good enough’ levels of insulation will be sufficient for effective heat pump operation, rather than the very high standards of insulation previously assumed to be necessary. This is reflected in the proposals to retain, rather than enhance, existing standards for insulation and thermal performance in the forthcoming Future Homes and Buildings Standard. [101, 102, 103]

Given these contextual changes and drivers, the evidence suggests that there is currently a greater need for innovation in the approaches for deploying existing insulation technologies cost-effectively, at scale and to high quality standards, rather than an urgent need for further innovations in specific insulation technologies. Having robust processes in place to ensure that the right type and amount of insulation is installed in the right properties, along with appropriate ventilation, will avoid further costly unintended consequences such as damp, mould, fire risk and overheating. Innovation is needed to ensure that existing insulation technologies can deliver carbon savings cost effectively as well as enhance a building’s fire resistance and climate resilience, provide health, wellbeing and cost benefits to building occupants and deliver wider societal and economic benefits.

Fire safety: In the wake of the 2017 Grenfell Tower disaster, there has been a heightened focus on fire safety. Insulation for remediated external wall systems and new builds must meet tougher fire safety requirements.

Estimates suggest that 6,220 to 8,890 mid-rise residential buildings with dwellings, and 190-330 mid-rise buildings without dwellings (hotels, student accommodation etc.), may require work to alleviate fire risk.[104] The cost to remediate external wall related fire risks for leasehold dwellings in mid-rise buildings is estimated to be between £3.1 billion and £5.3 billion.[105]

[100] Department for Business, Energy and Industrial Strategy (2019) Energy Innovation Needs Assessment: Sub-theme report - Building fabric
[101] HM Government (2024) The Future Homes and Buildings Standards: 2023 consultation
[102] Nesta (2024) Insulation impact: how much do UK houses really need?
[103] Wales Net Zero 2035 Challenge Group (2024) How could Wales heat and build homes and workspaces by 2035?
[104] Department for Levelling Up, Housing and Communities (2022) Estimating the prevalence and costs of external wall system life-safety fire risk in mid-rise residential buildings in England
[105] Department for Levelling Up, Housing and Communities (2022) Estimating the prevalence and costs of external wall system life-safety fire risk in mid-rise residential buildings in England

Damp and mould: From October 2025, Awaab's Law will require social landlords to investigate and resolve damp and mould in homes within set time periods.[106] This is expected to include recommending energy efficiency measures such as insulation alongside adequate ventilation, heating system upgrades and building maintenance measures.[107, 108]

The BRE estimates that excess cold and dampness in UK homes cost the NHS annually £857 million and £38 million respectively, with the potential annual savings to society from mitigating these problems estimated at £15.3 billion and £96 million respectively per year.[109] Other research links damp and cold housing to wider societal challenges including social isolation[110], poor mental health[111], absenteeism from school and work[112] and youth violence.[113]

Failed insulation schemes: High quality insulation and retrofit measures should decrease the risks of damp and mould, when installed appropriately. However, poor quality insulation retrofit works have introduced or worsened problems of damp, mould and decay in homes, including where Trustmark approved installers have undertaken the works.[114, 115, 116, 117, 118] This has occurred for cavity wall insulation, solid wall insulation and roof insulation, with remediation work necessary to remove inappropriate insulation materials. In some cases, homes have been deemed 'unmortgageable' due to inappropriate insulation.[119] In January 2025, following widespread failures in solid wall insulation, the UK government suspended 39 insulation installers, proposed major changes to the regulatory system and began plans for repairing failed installations.[120]

Cost of living crisis and fuel poverty: The UK nations have different definitions of fuel poverty, although all demonstrate that when energy prices increase, more households are at risk of fuel poverty. Improving insulation and energy efficiency in homes can help reduce the likelihood of households falling into fuel poverty. As energy prices increase the cost benefits of insulation for householders increase, and the return on investment for insulating non-domestic buildings is also improved.

Climate adaptation: Half of UK homes are already at risk of overheating.[121] It is predicted that under a 2°C global warming scenario, 90% of UK homes will overheat and in a 4oC scenario all UK homes will overheat. Building insulation can help reduce overheating risks and minimise the need for cooling, when appropriately designed and installed. However, overheating risks

[106] HM Government (2025) Awaab's Law to force landlords to fix dangerous homes
[107] HM Government (2024) Awaab's Law: Consultation on timescales for repairs in the social rented sector
[108] HM Government (2024) Understanding and addressing the health risks of damp and mould in the home
[109] BRE (2021) BRE report finds poor housing is costing NHS £1.4bn a year
[110] Benton, E. (2024) Damp and mould—the big picture. How do we tackle the damp and mould crisis in social housing: lessons from the UK
[111] Mohan, G. (2022) The impact of household energy poverty on the mental health of parents of young children
[112] mPower (2022) Person Centred Retrofit Summary Report
[113] LPAC (2022) Understanding Young Peoples Experiences of Violence in Lambeth
[114] HM Government (2019) Cavity wall insulation (CWI): Consumer guide to issues arising from installations
[115] BBC (2024) Homes insulated in government scheme go mouldy
[116] BBC (2024) 'Botched insulation means mushrooms grow on my walls'
[117] Inside Housing (2023) Welsh council agrees £3m plan to fix estate damaged by 'failed' insulation scheme
[118] House of Commons Library (2024) Spray foam insulation and mortgages
[119] House of Commons Library (2024) Spray foam insulation and mortgages
[120] HM Government (2025) Action taken to protect households with poor-quality insulation
[121] Climate Change Committee (2022) Addressing overheating risk in existing UK homes

can increase when too much insulation is installed without adequate ventilation, with the risks greater for certain property types e.g. top-floor and mid-floor flats.[122, 123] Other important adaptation considerations for building insulation, fabric and heating, include:

- The increase in negative health impacts from overheating, including an estimated tripling of heat-related deaths by 2050.
- Household heating demand in the winter is very likely to decrease due to warmer winters, and cooling demand is likely to increase in hotter summers if air conditioning uptake increases which may alter the pattern of peak electricity demand.
- Building fabric can be affected by flooding and intense rain, structural damage due to high winds and subsidence caused by drought. These cause harm to occupant health and wellbeing and create repair costs for homeowners.
- Increase and improve the guidance and incentives to address overheating in existing homes through retrofitting.

[122] DESNZ (2024) Energy Follow-up Survey
[123] Climate Change Committee (2022) Addressing overheating risk in existing UK homes

Heating and buildings innovation opportunities

Overview of technologies and tables of innovation needs

Building fabric insulation

Overview of building fabric insulation

Technology description: Building fabric insulation lowers demand for energy by reducing heat loss from the building envelope (roof, walls, floors, windows, doors etc.) in colder periods. A well-insulated - and well-ventilated - building can also reduce cooling demand in hotter periods. Insulation and ventilation must be considered concurrently. It is particularly important for building retrofit projects to take ventilation into account alongside insulation technologies, to avoid unintended consequences like damp, mould and structural decay.[124, 125] The EINAs focuses on loft, wall (cavity and solid wall) and floor insulation.

While most of the content is relevant to domestic and non-domestic buildings, most of the evidence referenced in this report refers to domestic buildings, as there is limited comparable information available on non-domestic properties.

Table of innovation needs

This section details key components and areas of technology innovation required to reduce cost and accelerate the deployment of the building insulation technologies assessed in this report. The 'Insulation' section above briefly addresses potential non-technological innovations for improving the quality of insulation deployment.

The evidence in the Heating, buildings and the energy system section suggests that existing insulation technologies, along with clean heating, should be sufficient in enabling the transition to low carbon buildings. However, there are emerging smart materials and technologies that may play a role in future insulation development[126].

The previous EINA report on building fabric in 2019[127] identified **improving performance, promoting a circular economy and reducing costs** as the three main objectives for innovation in building fabric. These objectives are all still highly relevant in 2025, given that factors including the COVID-19 pandemic and world events have impacted material prices and

[124] UK Government (2024) Understanding and addressing the health risks of damp and mould in the home
[125] DESNZ (2023) PAS 2035:2023 Retrofitted dwellings for improved energy efficiency - Specification and guidance
[126] A-1 Insulation (2024) Insulation Innovations: Future Trends and Technologies to Watch in the Industry
[127] Department for Business, Energy and Industrial Strategy (2019) Sub-theme report: Building fabric

slowed innovation timelines in the intervening period. Table 3 below presents the innovation needs that continue to be relevant, with progress updates.

The table in this section details the direct technology impacts of the innovations, as well as the other EINAs technologies that could benefit from innovation in these areas. Each innovation is assessed according to its likely impact on cost reduction and deployment for the relevant technology, with a qualitatively assessed 1 (very low) – 5 (very high) impact rating. Column descriptors within the table are defined as following:

- Technology: technologies where the innovation is applicable.
- Other impacts: other technology families that are indirectly impacted by this innovation.
- Cost reduction: how the innovation opportunity can reduce the overall costs of the technology, rated from 1 (low) to 5 (high).
- Barrier reduction: how the innovation opportunity can contribute to reducing barriers to deployment, rated from 1 (low) to 5 (high).
- Time frame: period over which the innovation could feasibly start to be adopted and have material implications for the UK energy system and Net Zero.

Table 3: Innovation needs in building insulation

Objective	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Improved and guaranteed performance of insulation materials Recent retrofit failures demonstrate ongoing need for performance improvement.	Increase quality and durability of insulation installations. Focus on improving the specification, installation and maintenance processes to ensure appropriate insulation and ventilation measures are installed in appropriate properties and suitably maintained (see 'Insulation' section).	New builds and existing properties, heating, ventilation and air conditioning (HVAC) technologies.	Effective insulation should reduce heating and cooling energy demand, reduce HVAC sizing and costs, and lower demand across energy networks.	3 – Improved installation quality results in lower customer fuel bills, lower maintenance costs, and longer durability and reduced risk of remediation costs. Improved business case through guaranteed return on investment.	3 – Reduces likelihood of underperformance and risks of unintended consequences. Higher degree of customer confidence.	2025 – 2030

Advancements in modelling and testing Retrofit failures highlight the performance gap between modelled theory and real-life results. Research and development in improving modelling and measurement is underway but innovative approaches are not yet mainstream e.g. the ‘Survey and Design’ cohort of Heat Pump Ready projects[128].	Unlock data collection, analysis and sharing across all stages of building construction and retrofit design to provide greater understanding of insulation and ventilation needs and building performance. Reduce risks of unintended consequences from low quality or inappropriate installations. Improve testing to provide evidence for ‘guaranteed performance’ of insulation materials (see row above). Explore / expand role of AI in modelling and testing.	New builds, existing properties, HVAC technologies.	Improved property data would help to optimise the design of retrofit measures, HVAC technologies and other energy-consuming building services.	3 – Smarter, faster modelling methods and more accurate data could cut costs from the design and installation stages. It could help to reduce on-site wastage through more accurate quantification of materials. Could help to avoid costly remediation due to low quality or inappropriate installations.	3 – Improvements to the survey, design and installation process could incentivise installers by improving their profitability and building trust with consumers. Could help build consumer confidence by getting solutions right first time. Better data could provide insights on what does and doesn’t work, and inform future policy and technology design.	2025 – 2030

[128] Heat Pump Ready (Accessed: 2025) Optimised Solutions Development Projects - heat pump roll-out

Objective	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Design for manufacture and assembly Limited evidence of progression into the mainstream, potentially delayed by global events (e.g. pandemic, supply chain crisis, rising energy costs etc).	Offsite / prefabricated construction and precision manufacturing for new builds and retrofits to increase the quality and speed of construction / installation and reduce construction / installation costs.	New builds and existing properties.	Minimal impact on other technology families.	3 – Reduces manufacturing, construction, installation and disposal costs, creating a stronger business case and improved return on investment for customers. Prefab is an export opportunity for the UK.	3 – Prefab has the potential to remove the disruptive element of retrofit and so could improve customer satisfaction and willingness to participate in insulation schemes.	2030 – 2035

Objective	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Low embodied carbon materials Increased understanding of the extent and impact of Scope 3 / supply chain emissions supports the need to continue efforts in reducing carbon content of materials, to reach Net Zero	Reduce the embodied emissions of building fabric across the whole lifecycle of materials, from resource extraction to disposal.	New builds, existing properties, HVAC systems and heat pumps	Minimal impact on other technology families.	1 – Currently low embodied carbon materials are more expensive than convention materials.[129] Usage could avoid carbon penalties.	2 – Decreases carbon impact of insulation materials, helping organisations reach net zero targets, directly or indirectly. Improved customer satisfaction for those driven by environmental values.	2030 – 2035

[129] Mendoca, P., and Vieira, C. (2022) Embodied carbon and economic cost analysis of a contemporary house design using local and reused materials

Components and costs

Costs for insulation vary greatly depending on whether the installation is for a new build or a retrofit, and whether the work is carried out individually by homeowners or at scale in area-wide insulation schemes led by national or local government or social landlords. Costs will also vary depending on whether installations are focused on insulation only or combined with wider planned or reactive maintenance measures or wider decarbonisation packages. Key costs for installing insulation include:

- **Project management:** any insulation installation will have project management time and costs associated with it. For individual buildings, the property owner would likely bear these costs, but for an area-wide scheme, the costs would likely sit with national or local government and would depend on the scale and complexity of the scheme, and whether the project management is delivered in-house or outsourced.
- **Training and accreditation:** outside of external wall insulation, home insulation installers are not legally required to have specific qualifications. Accredited courses and training sessions are available and encouraged in order to ensure quality, these include NVQ certificates and diplomas such as the NVQ in Insulation and Building Treatments (level 2 & 3) which range from £750 - £900[130]. Companies who are associated with TrustMark – the UK Government's quality assurance scheme for business – may have to pay small membership and assessment fees however these are kept low to avoid extra costs to consumers and businesses[131]. There are stricter requirements for Retrofit Coordinators, who must hold level 3 qualifications in build environments and a Level 5 Diploma in Retrofit Coordination and Risk Management, training and certification for this qualification can cost up to £2,000[132] and reflects the higher burden of responsibility for ensuring compliance to PAS2035 and delivery of retrofit work.
- **Identifying properties to insulate:** where area-wide insulation schemes have been undertaken, there are costs associated with identifying appropriate properties and defining eligibility criteria etc. This requires access to various data sets such as property and household information, smart meter data, EPC ratings, socio-economic data, energy grid data, details of previous local energy efficiency interventions or schemes etc. The availability and quality of these types of data is often inconsistent and can impact project costs and timelines for decision making. This activity may be embedded within wider local area energy planning processes or may be an output of energy system modelling (or 'digital twinning'). It often involves extensive stakeholder engagement. Local Area Energy Plans (LAEPs) that follow the Energy Systems Catapult methodology[133] tend to require consultant support priced at £100k-£200k per local authority (depending on scale, scope and complexity), require substantial local authority officer and stakeholder time and resource, and can take a year or more to complete.

130 City & Guilds (Accessed: 2025) Insulation and Building Treatments qualifications and training courses
131 TrustMark (Accessed: 2025) Frequently asked questions
132 Retrofit Academy (Accessed: 2025) Retrofit Academy, Level 5 Diploma
133 Energy Systems Catapult (Accessed: 2025) Local Area Energy Plans

- **Design, specification and approval:** depending on the scale of the insulation scheme, processes for designing and specifying insulation installations could involve teams of specialists including architects, engineers, fire safety experts, sustainability advisers, acousticians, planners, building control etc. For new build programmes, the costs for specifying insulation would likely be absorbed within the costs of the wider design and build process, unless building to particularly high standards of insulation where input from further specialists (e.g. Passivhaus certified) may be required, for example.
- **Resident engagement:** a cost that can be overlooked or underestimated is the cost of effectively engaging with and involving residents in retrofit schemes. Again, costs vary depending on the scale of the scheme and could include identifying households, community leaders and community groups, building and maintaining relationships, community events, door knocking and conversations with individual households, arranging for loft clearance or temporary storage for belongings during installations, aftercare, behaviour change support etc. Where residents refuse to participate or drop out of insulation schemes at various stages of the customer journey, this can add to engagement costs and project timescales.
- **Enabling works:** Scaffolding and other enabling works can add to the cost of insulation installations and are particularly expensive for mid- or high-rise buildings[134]. Where insulation is combined with other works to the property e.g. installing solar panels, costs for scaffolding and enabling works can be minimised per intervention. In some cases, repairs may be required before insulation can be installed e.g. where a roof is leaking or a property has structural problems. Evaluation of Whole House Retrofit projects found that actual enabling costs were far higher than estimated at the outset (~£1600 - £3000 per property, compared to an estimated £500)[135]. A sample of 14 whole house retrofit projects showed that enabling and repair works on average accounted for 26% of total costs[136].
- **Capital costs of materials:** depending on specification, in 2024 costs are in the approximate range of £10 per m^2 for fibreglass and polystyrene, £15 per m^2 for PIR board and mineral wool, £20+ per m^2 for sheep wool and polyurethane foam. These are the most common insulation materials, newer and more innovative materials such as aerogel have a higher cost (often over £100 per m^2 for an Aerogel blanket).
- **Labour costs for installation:** installation costs for a typical house (3 bed semi-detached which comprises 30% of houses) can range from £950 for loft insulation to over £12,000 for external solid wall insulation[137]. When determining installation costs, the key considerations are complexity, type and size of property. The easiest and therefore lowest cost installation would be a loft, where the is easy access and minimal disruption to the home. Conversely, solid wall or floor insulation may require extensive work to remove existing parts of the building which require refitting and renovating after

[134] Department for Business, Energy and Industrial Strategy (2017) What does it cost to retrofit homes?
[135] DESNZ (2024) Whole House Retrofit (WHR) and Social Housing Decarbonisation Fund Demonstrator (SHDF(D))
[136] DESNZ (2025) Demonstration of Energy Efficiency Potential (DEEP)
[137] GreenMatch (Accessed: 2025) House insulation costs in the UK

installation; these may also have a significant impact on the occupants and in some cases could require them to move for the duration of work.

- **Operational costs** in theory should be minimal for basic, correctly installed, roof insulation which has a typical lifespan of 15-30 years, with some types (e.g. rockwool) lasting up to 60 years[138]. An annual maintenance check is important to ensure that roof insulation is dry, in good condition and provides full coverage. For some types of insulation, for example solid wall insulation, warranties on the product may require evidence of regular maintenance, such as replacing sealants after a certain number of years. Where the insulation is funded or installed by anyone other than the building occupant i.e. a landlord or government funded scheme, it is important to identify contractually which party is responsible for maintenance and the associated costs prior to installation. A 25-year guarantee is considered standard for solid wall insulation products and installations[139]. External cladding and insulation can also impact building insurance, with potentially combustible types of external insulation increasing insurance premiums[140]. Homeowners or leaseholders/landlords may have to factor this into account when setting rent or utility charges, with higher insurance prices likely being passed to the occupier. Retrofit installers and builders are also facing higher professional indemnity insurance premiums and restrictions with regards to installing external cladding and insulation given the greater scrutiny post-Grenfell[141].
- **Removal / disposal:** The removal costs depend heavily on the type, condition, and accessibility of home insulation. For a typical house (3 bedroom semi-detached) removing loft insulation made from rockwool or fiberglass can cost around £700[142]. More difficult insulations such as spray foam and cavity wall insulation can cost between £2,000 - £3,200[143] for the same property type and size; this reflects the higher amount of labour required and the need for specialist disposal due to the potential toxicity of spray foam compared to other insulation types which can be easily disposed of. While non-hazardous insulation can be disposed of by general means such as refuse and recycling centres, there may sometimes be a small charge attached to compensate for the high volume of waste. Skips are a popular choice for disposal but must be hired for a charge of typically £150 - £300 depending on size[144]. External cladding panels which are uncontaminated or in good condition can be recycled and reused, minimising waste.
- **Remediation:** appropriately specified and installed insulation should not require remediation costs. Unfortunately, as discussed in the The heating and buildings landscape in the UK, land, remediation works on the grounds of fire risk, damp and mould have potentially been the costliest element of insulation schemes to date, with forecasts of approximately £4.7 billion to remediate fire risks in UK buildings alone[145]. Hence the recommendation to focus on getting insulation schemes 'right first time', to

[138] Sealed (Accessed: 2025) How long does insulation last?
[139] LABC (2022) External wall insulation
[140] Financial Conduct Authority (2023) Leaseholder buildings insurance | FCA
[141] Marsh (2018) Professional Indemnity: Cladding Risks
[142] Insulation Extract (2022) Loft Insulation Removal Costs Explained
[143] Checkatrade (2024) What's the Cost of Removing Roof Foam Insulation in 2024?
[144] Checkatrade (2024) What Are Skip Hire Prices In 2024?
[145] MHCLG (2025) Building Safety Remediation: monthly data release - September 2025 - GOV.UK

minimise costly remediation, disruption and distress for occupants, waste to landfill and associated embodied emissions of wasted building materials.

Heat pumps

Overview of heat pumps

Heat pumps powered by low carbon electricity are key to the Net Zero transition agenda in the UK and are expected to play a key role in becoming the primary means of decarbonising space and water heating.[146]

A heat pump uses technology similar to that found in a refrigerator, but in reverse, extracting heat from an energy source, then transferring it to where it is needed. More specifically, heat pumps move thermal energy by using electrical energy to drive a vapour compression refrigeration cycle. As such, in order to be a low carbon technology, heat pumps rely on a low carbon electricity grid.

The current available heat pump technologies can be up to 3 – 5 times more efficient[147] than a natural gas boiler and are expected to play an important role especially in decarbonising low and medium temperature heating in buildings. The majority of deployed heat pumps are expected to be small scale domestic units. However, large heat pumps can also address industrial and district heating needs with more innovation and design improvements.[148]

The heat pumps discussed here include Air Source Heat Pumps, Ground Source Heat Pumps and Water Source Heat Pumps with the differences between these technologies are described in the introduction section.

To achieve the required deployment numbers, market barriers will need to be addressed. The rebalancing of electricity and gas costs, expansion of supply chains and commitment to funding and delivery plans to make buildings energy efficient, heat pump ready and low carbon will all be essential.

Table of innovation needs

The tables in this section detail the direct technology impacts of the innovations, as well as the other EINAs technologies that could benefit from innovation in these areas. Each innovation is assessed according to its likely impact on cost reduction and deployment for the relevant technology, with a qualitatively assessed 1 (very low) – 5 (very high) impact rating. The timeframe column refers to the time period within which the innovation could be expected to have material implications for the UK energy system and Net Zero with investment and innovation. Column descriptors within the table are defined as following:

- Technology: technologies where the innovation is applicable.

[146] NAO (2024) Decarbonising Home Heating.
[147] Summarised from IEA (2024) Heat Pumps - Energy System
[148] IEA (2022), The Future of Heat Pumps: The Future of Heat Pumps – Analysis - IEA

- Other impacts: other technology families that are indirectly impacted by this innovation.
- Cost reduction: how the innovation opportunity can reduce the overall costs of the technology, rated from 1 (low) to 5 (high).
- Barrier reduction: how the innovation opportunity can contribute to reducing barriers to deployment, rated from 1 (low) to 5 (high).
- Time frame: period over which the innovation could feasibly be adopted and start scaling.

Table 4: Innovation needs for heat pumps

Component	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
System	Refrigerant R&D – Low Global Warming Potential (GWP) refrigerants,[149] refrigerants that can allow high efficiencies at high temperatures (above 60°C) R&D for new heat pumps components that can allow higher efficiencies and temperatures such as new compressors (required particularly for natural and low-GWP refrigerants that need higher pressures), solid state technologies[150], [151]:	All heat pumps	N/A	4 – System improvements impacts the long-term running cost of heat pumps, which affects the overall lifecycle cost.	4 – Improved performance and reduction in running cost which makes up 55-65% of total heat pump lifecycle cost will positively affect overall affordability which is a major barrier in their widespread adoption[152].This may also reduce or remove the need for emitter upgrades, reducing the cost, time and disruption of installation.	2025 – 2035

[149] HM Government (2021), UK Net Zero Research and Innovation Framework, UK Net Zero Research and Innovation Framework
[150] BEIS (2021), Heat Pump Ready – Background on Innovation Needs: Heat Pump Ready Programme: background on innovation needs (publishing.service.gov.uk)
[151] CCC (2021), Sixth Carbon Budget – Buildings: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Buildings.pdf
[152] Nesta (2022) How to Reduce Cost of Heat Pumps

Component	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Installation	Integration of plug and play hardware and software to improve ease of installation, require fewer adjustment to settings at installation, commissioning and operation, alongside easy-to-use modelling tools to design and specify systems more accurately, including sizing and controls of buffer vessels Include pre-plumbed or integrated system elements such as hot water cylinders and buffer tanks into heat pump enclosures, alongside modular heat pump systems that allow a range of modules to be connected together to form a complete working system Ground loops design and deployment techniques[153, 154, 155, 156]	All heat pumps	Potentially other domestic low carbon technologies	3 – Improvements to installations will impact the capital costs, which is a significant barrier and can lead to better performance and reducing performance gaps.	4 – Rate of deployment can be improved if disruptions and complexities are reduced during installation and an increased workforce that is competent in this process Cost of deployment, which is closely linked to the rate of deployment, can be reduced through increased experience levels of the supply chain and improved learning rates	2025 – 2035

153 BEIS (2021) Heat Pump Ready Programme: background on innovation needs
154 Heat Pump Association (2023) Unlocking Widescale Heat Pump Deployment
155 The Scottish Government (2010) Low Carbon Equipment and Building Regulations
156 IEA (2022) The Future of Heat Pumps

Component	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Manufacture	Integration of standardised or modular components and systems that can be mass produced and benefit from industrialised manufacturing Increase integration of automation and robotics to improve manufacturing capabilities by increasing precision and reducing production time and cost. This is likely to apply primarily to sub-components given manufacturing scales required for automation. Improve ability of compressors to operate across a range of conditions to enable improved real world performance Develop heat pump designs to enable a circular economy for easy re-use of parts[157], [158]:	All heat pumps	Potentially other domestic low carbon technologies	3 – Improvements to manufacturing capabilities will impact capital costs and volume of domestic manufacturing	4 – Rate of deployment can be improved with better manufacturing capabilities, as this will reduce cost through increase efficiency, product quality and availability	2030 – 2035

[157] US Department of Energy (2016) Heat Pump Supply Chains and Manufacturing Competitiveness Considerations
[158] IEA (2022) The Future of Heat Pumps

Component	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
Operation & Maintenance (O&M)	Digitalisation and integration of control systems to enhance system optimisation (inclusive of use of AI), monitoring and fault detection (remote diagnostics and predictive maintenance) and for improved data collection and enable effective grid management. Development of optimised controls to allow demand shifting in response to time of use tariffs and other price signals (inclusive of use of AI to optimise operation patterns) Open-source control systems that can link different heat pumps with products such as batteries, with user interfaces which are easier to understand and avoid incorrect operation practices	All heat pump	Potentially other domestic low carbon technologies	3 – Improved O&M will reduce running cost with improved operation efficiency Performance impacts the long-term running cost of heat pumps, which affects the overall lifecycle cost.	3 – Improved O&M allows for system to operate more efficiently and safely, which will help increase deployment rate Improved performance and reduction in running cost which makes up 55-65% of total heat pump lifecycle cost will positively affect overall affordability which is a major barrier in their widespread adoption.[159]	2025 – 2030

[159] Nesta (2022) How to reduce cost of heat pumps

Financing	Improve financial and service integration by providing[160] [161]: Integration of financial offering with flexibility services[162] One-stop-shop model that serve as a single point of contact for customers which includes financing, project management, design and support services. This will reduce information asymmetry, improve customer experience by making it less fragmented and reducing the duration of the consumer journey, and number of dropout points. Development of Heat-as-a-Service (HaaS) and Energy-as-a-Service (EaaS) type services and subscription models. HaaS focusses on reduction of upfront costs and billing based on heat generation and electricity consumption, along with additional services such as maintenance. EaaS is a power purchase agreement with homeowners to provide lower energy costs, with no up-front capital for technologies (not exclusive to heat pumps) and ongoing services such as maintenance. This also allows service	All heat pumps	Potentially other domestic low carbon technologies	3 – Improved financing can help remove barriers with high CAPEX	3 – Improved financial offerings allows for better consumer perception and experience, thus reducing deployment barriers. Offerings based on an integrated supply chain are expected to more effective deployment. An integrated one-stop-shop model can lead to improved customer experience and reduce the number of dropout points. This would mitigate against the current complex and lengthy consumer experience.	2025 - 2030

Component	Innovation opportunity	Technology	Other impacts	Cost reduction	Barrier reduction	Time frame
	providers to help consumers pick the best low carbon system when it's time to replace existing system. [163] [164] Availability of financial instruments such as Property Linked Finance (PLF) can also be provided to support homeowners access affordable funding for environmental improvements by linking the finance to the property instead of the owner[165]					

[160] BEIS (2021), Heat Pump Ready Heat Pump Ready Programme: background on innovation needs
[161] Energy Systems Catapult (2019) Introduction to Heat as a Service
[162] HM Government (2021) UK Net Zero Research and Innovation Framework
[163] Energy Systems Catapult (2019) SSH2 Heat as a Service
[164] E.ON (2024) Green Finance Accelerator Discovery Phase Evidence Report: E.ON's Optimised Energy as a Service
[165] Green Finance Institute (2024) A greenprint for Property Linked Finance in the UK

Components and costs

While heat pumps have been identified in the UK as one of the primary technologies for the decarbonisation of heat in homes,[166] the current capital cost and long payback period driven by high electricity prices relative to gas are seen as key barriers to their widespread adoption. To unlock demand for heat pumps in the UK, the cost barriers will have to be addressed, while also unlocking in parallel other challenges such as the current friction in the customer journey.

Under the current policy and market conditions, NESTA estimate that upfront, running and installation cost make up approximately 15-20%, 55-65% and 20% respectively of the total cost of a heat pump over its lifetime. A reduction across these cost components along with consistent operational efficiency, product offering, and customer journey will be required to make heat pumps widely affordable. Initiatives in reducing running costs such as switching environmental levies from electricity to gas, increasing heat pump efficiencies and giving households access to discounted tariff for electricity will be able to bring whole life cost of heat pumps closer to that of a gas boiler.

Currently, the CAPEX of heat pumps in the UK is high, particularly for domestic users when compared with boilers, which are the incumbent technology. Air-to-water and ground/water source heat pumps respectively have a median upfront cost of around £10,500 and £20,000 in 2021, with a high cost variability depending on each individual home. However, policies are currently in place to address the high CAPEX, such as grants offered through the Boiler Upgrade Scheme, which has been increased to £7,500 for ASHP, GSHP and WSHP.[167]

The IEA offers insights into how UK costs compare to other countries by looking at the levelised cost of heating for air-to-air heat pump (AAHP), air-to-water heat pump (AWHP), and gas boilers accounting for fuel price sensitivity in 2021 and 2022 for selected countries.[168] This data shows that the levelised cost of AAHP and AWHP in the UK is comparable with the European market once subsidised CAPEX is accounted for, and second highest only to Germany when not accounting for the grant scheme.

The key identified cost components for heat pumps for the EINA assessment are broken down into pre-installation and installation capital costs as below:[169]

- **Heat Pump Unit:** The main heat pump unit, which will include key components such as a compressor, two heat exchangers (condenser and evaporator), a thermal expansion valve and refrigerant.
- **Pipework and Ancillary parts:** Ancillary parts that are required for the installation of a heat pump systems in a domestic setting, which will include cylinder or buffer vessel, pipes, valves, pumps, electrical connection, emitters.

[166] NAO (2024) Decarbonising home heating
[167] UK Government (2024) Apply for the Boiler Upgrade Scheme: What you can get
[168] IEA (Nov 2022) Levelised cost of heating for air-to-air and air-to-water heat pumps and gas boilers for selected countries, and sensitivity to fuel prices
[169] CIBSE (2022) AM17 Heat pump installations for large non-domestic buildings

- **External plantroom/Acoustic attenuation:** External enclosure for a heat pump, which in the case of a domestic unit can be excluded if no additional acoustic attenuation is needed.
- **Installation and Commissioning Cost:** The cost of commissioning and labour to install a heat pump.
- **O&M electricity:** Electricity associated with running the heat pump.
- **O&M maintenance:** Operations and maintenance costs, accounting for check-ups and breakdowns.
- **Decommissioning:** Costs associated with the decommissioning of the unit, including the correct disposal of refrigerant.
- **Ground work (GSHP & WSHP):** enabling works, permitting costs/ abstraction charges/ site testing, collector system.
- Enabling works for retrofit applications including changes to existing building fabric due to reduced demand, changes to terminal units/distribution system to enable lower temperatures, structural works to support new equipment and electrical infrastructures upgrades.

Heat networks

Overview of heat networks

Heat networks are an energy distribution system, working by connecting buildings via piping to a centralised heat or cooling generation source. Heat networks are flexible and can make use of different heat or cooling sources, including recovery of low carbon waste heat, or naturally occurring sources such as geothermal or rivers.[170]

While in 2023 heat networks provided approximately 2-3% of heat in the UK, it is projected that this proportion will need to increase to meet the Net Zero target by 2050.[171] Heat networks have been identified as a key decarbonisation technology for the built environment, for example in the CCC Net Zero Balanced scenario, and DESNZ targets aim for heat networks to cover 20% of heat required for buildings by 2050.[172],[173] Networks providing both heating and cooling, and balanced or ambient temperature networks such as 5th Generation Networks have the potential to play a role in adaptation, and can support cost efficiency for installation and operation.

The investment potential by 2050 is estimated at £60-80 billion,[174] with the 'Heat Network Zoning' initiative, which was implemented by the 'Energy Act 2023', expected to be core to this

170 DESNZ (2024) UK heat networks: market overview
171 DESNZ (2024) Heat network zoning: overview
172 CCC (2022) Independent Assessment: The UK's Heat and Buildings Strategy March 2022
173 DESNZ (2024) Heat network zoning
174 DESNZ (2024) UK heat networks: market overview

growth.[175] Heat Network growth will require certain types of buildings and low carbon heat sources be connected to a network within a prescribed timeframe, to ensure economies of scale is reached providing the best outcomes for everyone connected.[176]

Heat networks can have different scales, from small clusters of buildings (communal heating) to city wide networks (district heating). Heat networks generally have a higher commercial feasibility in a high-density urban area or near large anchor loads for both cooling and heating, as this enables an efficient use of a centralised energy source and minimises the distribution system and the associated losses.

Heat network technology can be grouped by the distribution water temperature. Early 1st and 2nd Generation networks were designed on-site for high temperatures (steam) and pressure. In recent years, and linked to the transition to Net Zero, heat network distribution temperature has significantly reduced, with current 5th Generation networks running on low 'ambient' temperatures. The lower distribution and return temperatures allow heat networks to integrate both heating and cooling generation technologies, maximise energy sharing and heat pump efficiencies and also alleviate the Urban Heat Island (UHI) effect by capturing rejected heat in urban environments.

Potential role in the UK energy system

Because of their inherent flexibility and ability to serve a wide number of customers, heat networks have been identified as a cost-effective solution to reduce carbon emissions from heating and hot water with a potential to utilise more sources of waste heat. Heat networks can also support cooling urban and non-domestic properties which are at increasing risk of overheating. They also have the potential to support the development of a stable and flexible energy system, mainly through their ability to provide large amounts of thermal storage and connection to multiple energy sources, allowing them to store energy flexibly and use it when it is most needed. [177,178]

Innovation needs

Table 5: Innovation needs for heat networks

Component	Innovation opportunity	Timeframe
Technology	Example actions for technology innovation [179]: Develop tools that help increase accuracy of peak demand and heat demand estimates	Short term

[175] DESNZ (2024) Heat network zoning
[176] DESNZ (2024) Heat network zoning: overview
[177] DESNZ (2024) UK heat networks: market overview
[178] Energy System Catapult (2020) Storage & Flexibility Thermal Energy Storage for Heat Networks
[179] Energy Systems Catapult (2018) District Heat Networks in the UK

Component	Innovation opportunity	Timeframe
	Technology development to promote quick installations, including enabling works within homes Innovate and reduce cost of Heat Interface Unit (HIU) Optimisation through simplification and design for manufacture, value engineering and optimisation of system solution	
Thermal Energy Storage (TES) and Energy Flexibility	Development of new early stage storage technologies and support for commercialisation (high-density storage; phase-change; inter-seasonal storage)[180] Demonstration and deployment of integrated solutions in building providing energy flexibility through the use of integrated TES and heat and power systems[181] Support access to balancing and flexibility markets for heat networks [182]	Short-Medium term
Network distribution	Example of innovation required for network distribution systems[183]: Implementing trenchless technology (i.e. drilling tunnels underneath the surface)	Short-Medium term
Cost	Example actions to innovate cost aspect of heat network include[184]: Improve design work and surveying at early stages to realise greatest cost savings Share civil engineering costs between utilities working in the same region	Short-Medium term
Knowledge management	Establish a 'District Heating Knowledge Centre' to share learning and disseminate current best practice	Short term

[180] Energy System Catapult (2020) Storage & Flexibility Thermal Energy Storage for Heat Networks
[181] Energy System Catapult (2020) Storage & Flexibility Thermal Energy Storage for Heat Networks
[182] Energy System Catapult (2020) Storage & Flexibility Thermal Energy Storage for Heat Networks
[183] Energy Systems Catapult (2018) District Heat Networks in the UK
[184] Energy Systems Catapult (2018) District Heat Networks in the UK

Component	Innovation opportunity	Timeframe
research and training	and outputs of other innovation. Create one place to bring stakeholders together.[185]	

[185] Energy Systems Catapult (2018) District Heat Networks in the UK - Overview

System benefits from innovation in heating and buildings

System modelling to assess the potential impact of innovation in key net zero technologies was conducted using UKTIMES, an energy system model of the UK that was developed by UCL and the UK Department of Business, Energy and Industrial Strategy (now the Department for Energy Security and Net Zero). For each of the selected technologies, three levels of innovation were developed representing a low, medium and high innovation case for the technology. The low innovation level represents a business-as-usual case where innovation follows recent trends or is generally limited, whilst the high innovation case represents significant innovation in the technology to decrease costs and improve efficiencies.

The low, medium and high innovation cases were each run against three different hypothetical scenarios which were developed by DESNZ to represent potential routes to net zero for the UK, namely Minimally Constrained, High Hydrogen and High Diversification. They do not necessarily represent government policy but were selected due to their differing constraints which provide a more diverse set of outputs and insights. A summary of each is presented below, a more in-depth description can be found in the EINAs Methodology report.

- **Minimally Constrained:** Designed to show the largest potential impacts from innovation investments by minimising the number of constraints on the energy system. UK Government data assumptions are used across the scenario.
- **High Hydrogen:** Based on the Minimally Constrained scenario, with a range of constraints added to force hydrogen use across the economy. These constraints are based on estimates of H2 demand ranges in the DESNZ Hydrogen transport and storage networks pathway policy paper published in 2023, and provisional figures from DESNZ sector teams that are set to be refined further for CB7. A maximum hydrogen consumption in each sector and a minimum overall level of consumption is applied in each year from 2035 to 2050.
- **High Diversification:** Based on the Minimally Constrained scenario, this scenario aims to be more energy secure through two means, 1) limiting imports of key commodities to reduce UK reliance on overseas resources, and 2) diversifying resource and technology use across the economy to limit the impacts of any supply interruptions, price rises or technology failures.

The results presented below demonstrate the potential impact of innovation for a specific technology on achieving net zero within the confines of the scenario. In each model run for a specific technology, all other technologies are held at their low innovation case so that the impact on the UK energy system of that technology can be isolated. Changing the costs and performance of technologies through innovation can have both direct and indirect consequences:

- Direct consequences are a reduction in cost or an improvement in the quality of the energy service supplied by the technology. Only cost reductions are examined in the UK TIMES energy system model.
- Indirect consequences are changes to the wider system caused by a relative change of cost of a technology relative to other technologies. If the deployment of a technology increases due to a lower cost and the deployment of alternative technologies reduces then a cost reduction will be realised. This cost reduction will be lower than the direct cost reduction would have occurred if the new technology had already been used at lower innovation levels. More profound changes could also occur across the energy system, for example changes in total electricity consumption or in the relative rate of decarbonisation between sectors of the economy.

We have not considered rebound effects where lower costs of energy due to innovation investments lead to higher energy service consumption. An elastic demand version of UK TIMES could be used to explore potential rebound effects of innovation investments.

The below analysis refers to only insulation and heat pump technologies assessed by the EINAs. It should be noted that given these results are an output of the system modelling and the three hypothetical scenarios developed for the EINAs that they do not reflect UK gov deployment targets and ambitions.

Insulation

Based on UK TIMES modelling in this analysis, roof and floor insulation have limited innovation potential in terms of overall system cost reduction (i.e. all innovation levels have the same system cost). Floor insulation, while reducing costs across innovation levels, does not have higher deployment in any of the innovation levels (aside from their high innovation run in High Diversification, where both roof and floor insulation measures are deployed). These outcomes might reflect the lower economic value of deploying these types of insulation, as there is a trade-off between cost of insulation measure and associated savings from increased energy efficiency, and that the model does not require houses to be highly insulated to value heat pumps as more cost efficient in decarbonising heating.

Wall insulation does not have increased capacity at the medium innovation level for Minimally Constrained and High Hydrogen scenarios. However, at the high innovation level, capacity increases to 27 TWh of heating demand savings in Minimally Constrained and High Hydrogen in 2050.

Wall insulation plays a significantly larger role in the High Diversification scenario, especially in the high innovation run, where there is an additional 3 TWh of heating demand savings by 2050. Figure 2 below shows the impact of different innovations levels across technologies in High Diversification, where capacity denotes the amount of heating demand saved through insulation measures. Other scenarios have no wall insulation deployment except for the high innovation run for the technology.

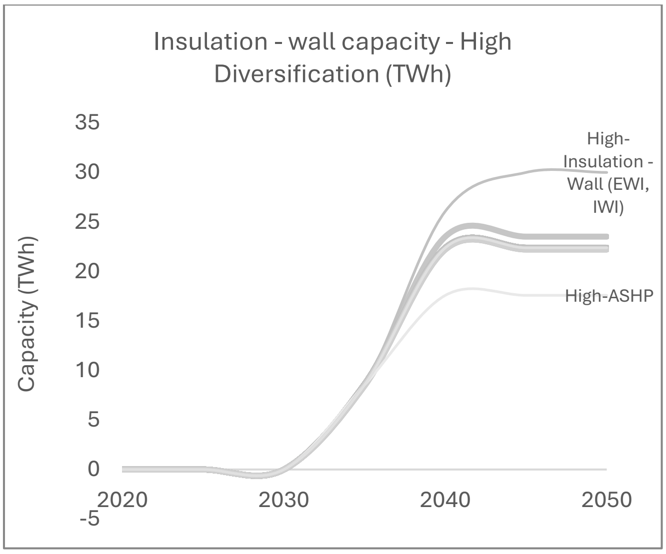

Figure 2: Wall insulation capacity (TWh) over time across different innovation runs (low, medium and high levels for each technology) in the High Diversification scenario

In High Diversification, the system value of insulation increases significantly due to the increased need for domestic energy generation as well as higher grid diversity which relies on a higher share of comparatively expensive nuclear energy. Cost savings for insulation are primarily driven by innovation in wall insulation with cumulative savings in the High Diversification scenario reaching £18.9 billion in 2050 at the high innovation level. Savings across Minimally Constrained and High Hydrogen are more modest, reaching £4.9 billion.

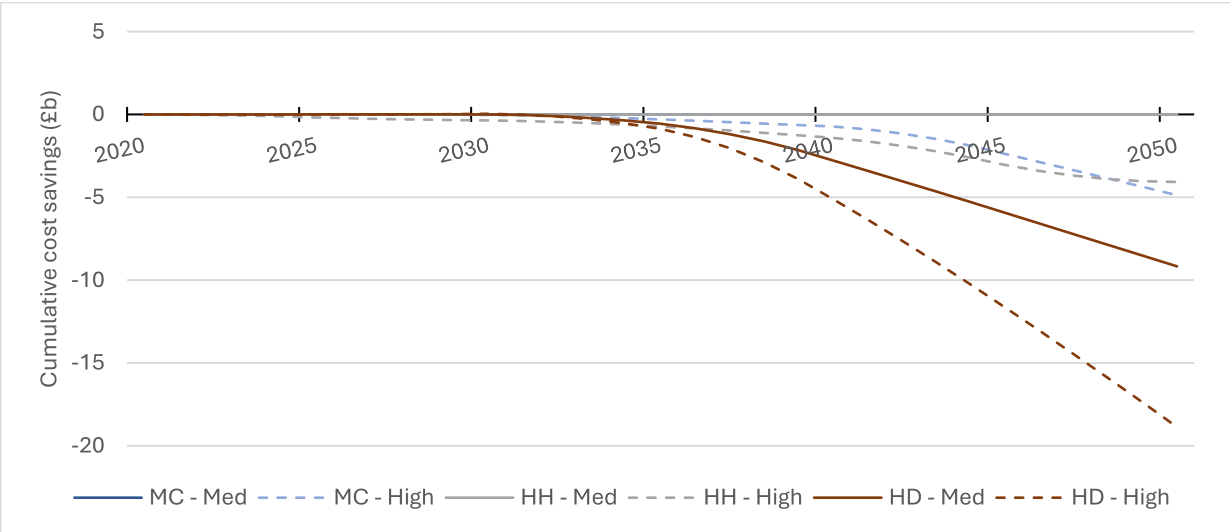

Figure 3: Cumulative cost savings (in real 2022 £) to 2050 for differing levels of innovation in wall insulation, compared to base all low innovation case

Heat pumps

This section covers modelling results for ASHPs and WSHPs for heat networks. While there are no model results for GSHPs in UK TIMES, this is in part due to spatial limitations of the model (whereby WSHPs and GSHPs are not impacted by geography) as well as challenges in modelling heat networks, where GSHPs are expected to play a larger role.

ASHPs are integral to achieving net zero across all innovation runs. Deployment of ASHPs reaches the assumed maximum feasible yearly installation level in most innovation runs, as evidenced by its deployment constraint flag in the modelling. This means that the deployment of ASHP is limited maximum yearly deployment rates, based on expected feasible installation capacity. In the high innovation case for ASHP, the deployment limit is relaxed from 1.5 million heat pumps per year to 2 million heat pumps per year, but even this higher level of deployment is reached in 2035–2045. This can be observed in Figure 4, where ASHPs reach between 250 to 300 TWh of heat provision (denoted below as generation) across all runs.

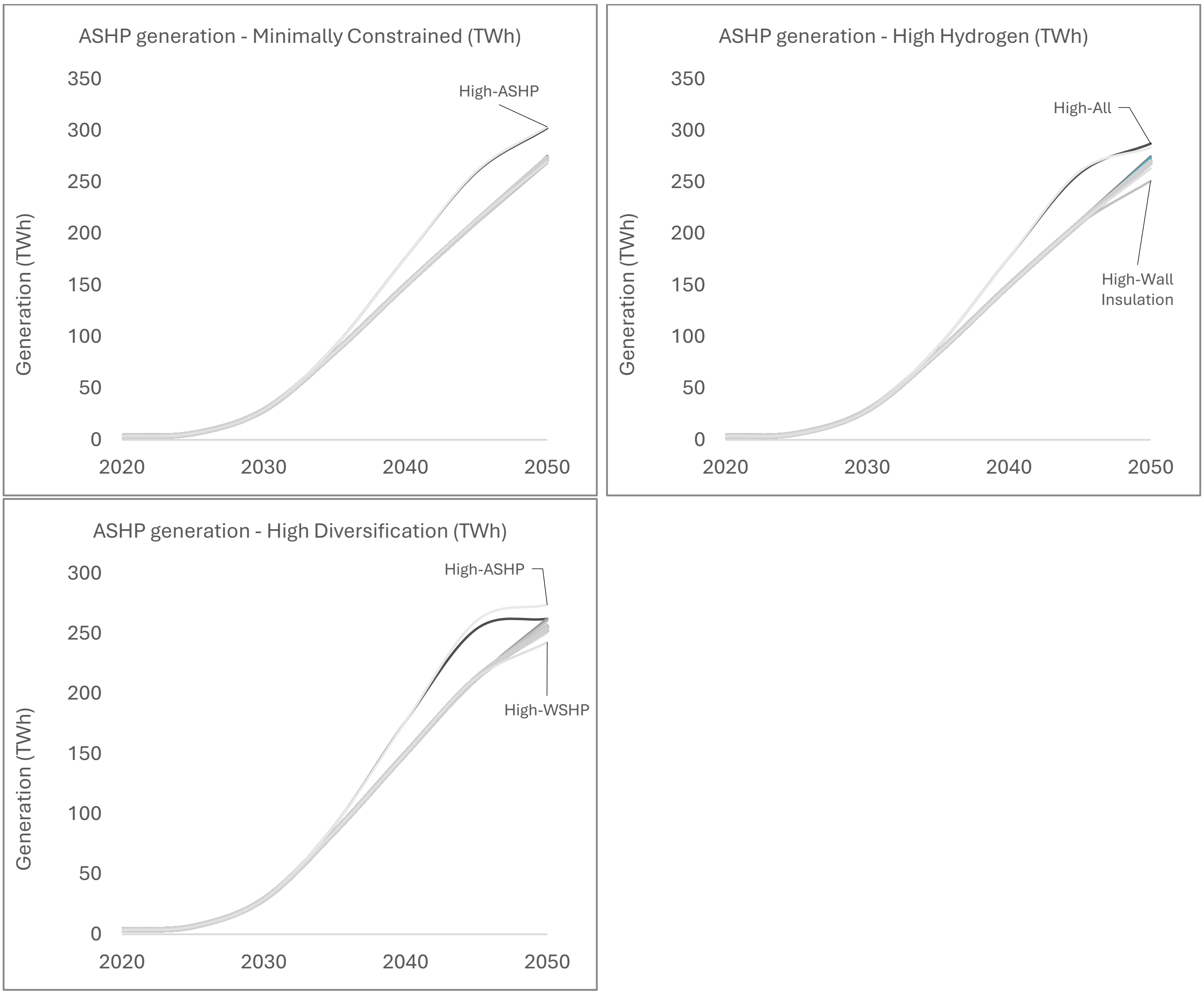

Figure 4: ASHP generation (TWh) over time across different innovation runs (low, medium and high levels for each technology) in all three scenarios

As a result of the importance of ASHP in achieving net zero by 2050 and the high levels of deployment, very significant cost savings could be achieved through innovation in the technology. Cumulative cost savings in the High Diversification scenario at the high innovation level reach £110.8 billion in 2050 compared to £67.8 billion and £71.7 billion in the High Hydrogen and Minimally Constrained scenarios respectively. Within the high innovation runs a significant portion of additional system savings is driven by the relaxation of the ASHP deployment limit compared to the medium innovation run, where cumulative system savings driven solely by cost and efficiency improvements reach approximately £42bn by 2050 across scenarios.

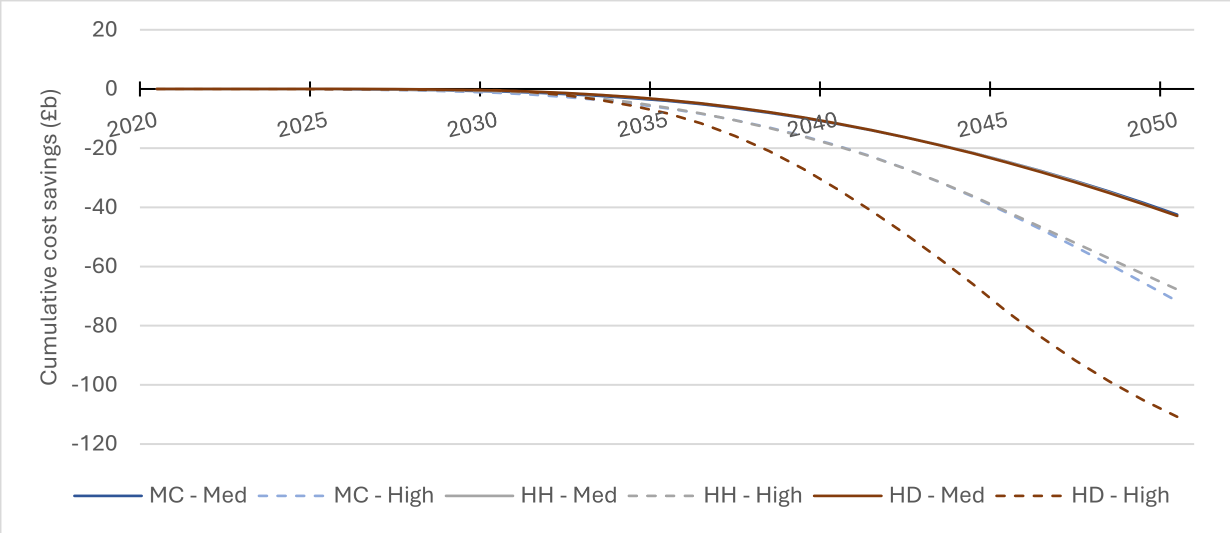

Figure 5: Cumulative cost savings (in real 2022 £) to 2050 for differing levels of innovation in ASHPs, compared to base all low innovation case

In Minimally Constrained, innovation in WSHP (used for supplying heat to heat networks in UK TIMES) significantly increases its deployment, with a 2-fold increase at the medium innovation level and a 3-fold increase at the high innovation level by 2050, compared to all low Minimally Constrained case. This is also observed for High Hydrogen, where 5–8-fold increase is observed in their innovation runs. In High Diversification WSHPs are widely deployed even in the low innovation run, with further increases as cost reductions are assumed for these technologies.

As noted above, due to UK TIMES spatial limitations, such extensive deployment of WSHPs for heat networks does not factor proximity of suitable water resources to heat demand, and therefore an overestimation of WHSP use. Rather, this result should be considered as proxy for the level of heat network deployment based on this modelling exercise. It is much more likely that heat provision for heat networks will be from large scale ASHPs (which could not be modelled within UK TIMES), GSHPs, waste heat and other sources.

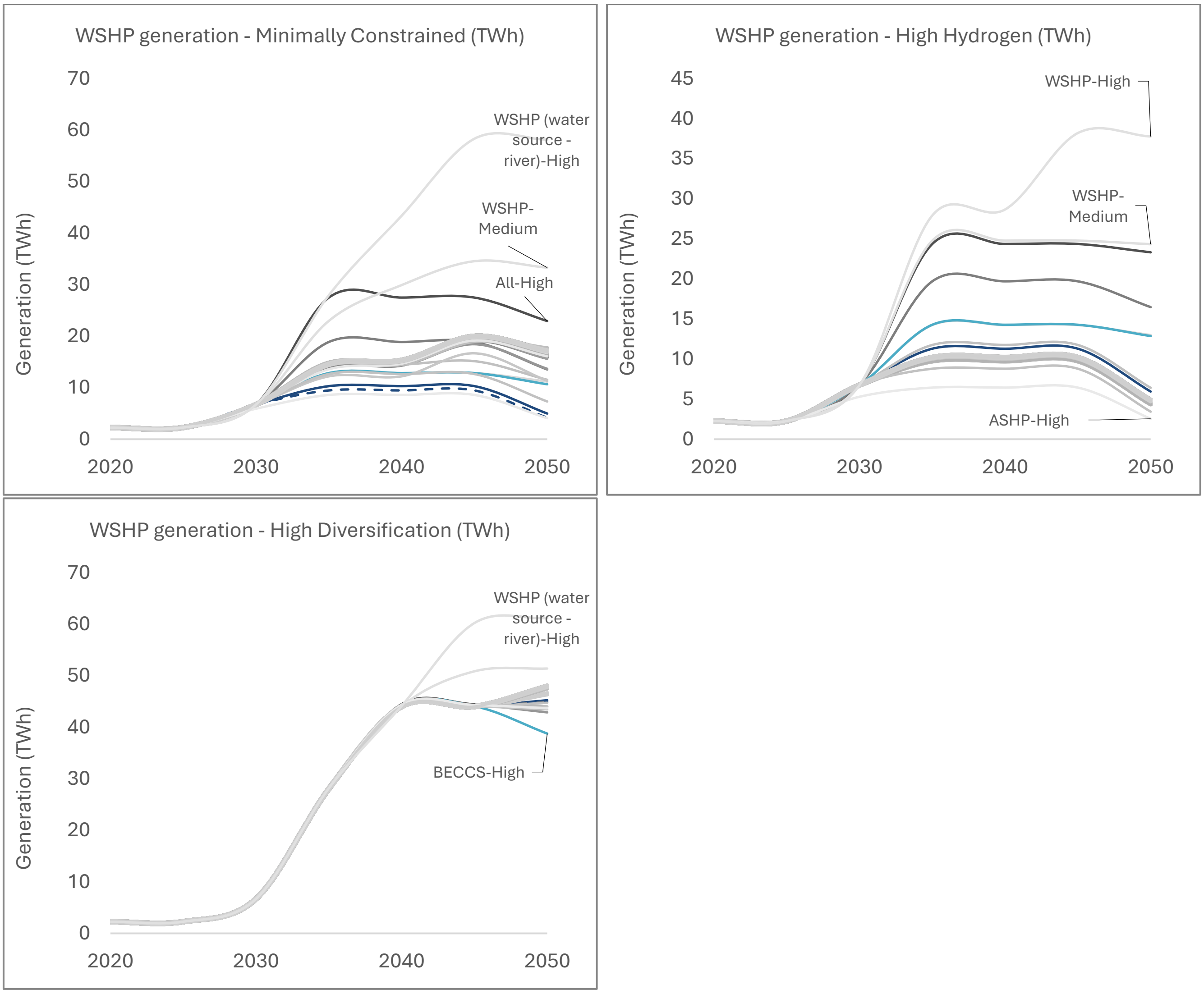

Figure 6: WSHP generation (TWh) over time across different innovation runs (low, medium and high levels for each technology) in all three scenarios

Given the sensitivities of the model to innovation in WSHP, significant cumulative cost savings can be realised at higher innovation levels across scenarios. Cumulative cost savings at the high innovation level in the High Diversification level reaches £17.8 billion in 2050, whilst it reaches £8.7 billion in Minimally Constrained and £7.4 billion in the High Hydrogen scenario.

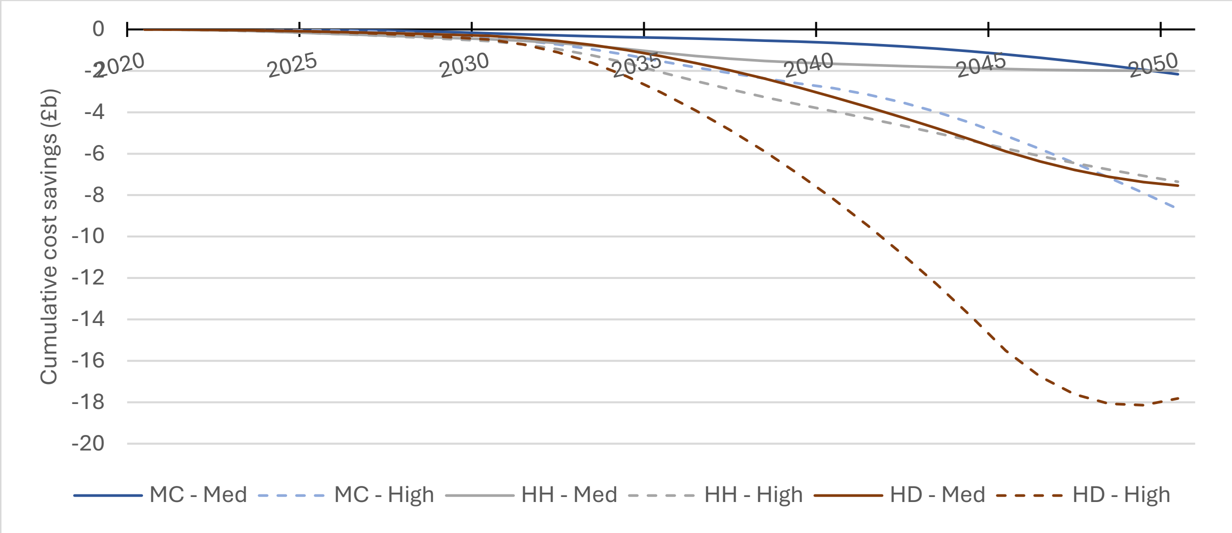

Figure 7: Cumulative cost savings (in real 2022 £) to 2050 for differing levels of innovation in WSHPs, compared to base all low innovation case

Innovations in WSHP have an impact on the generation of a range of other technologies in 2050 in the Minimally Constrained scenario. As discussed, when innovated WSHP deployment increases significantly, but it also drives down the generation of offshore wind and hydrogen technologies as energy demands on the system are lowered.

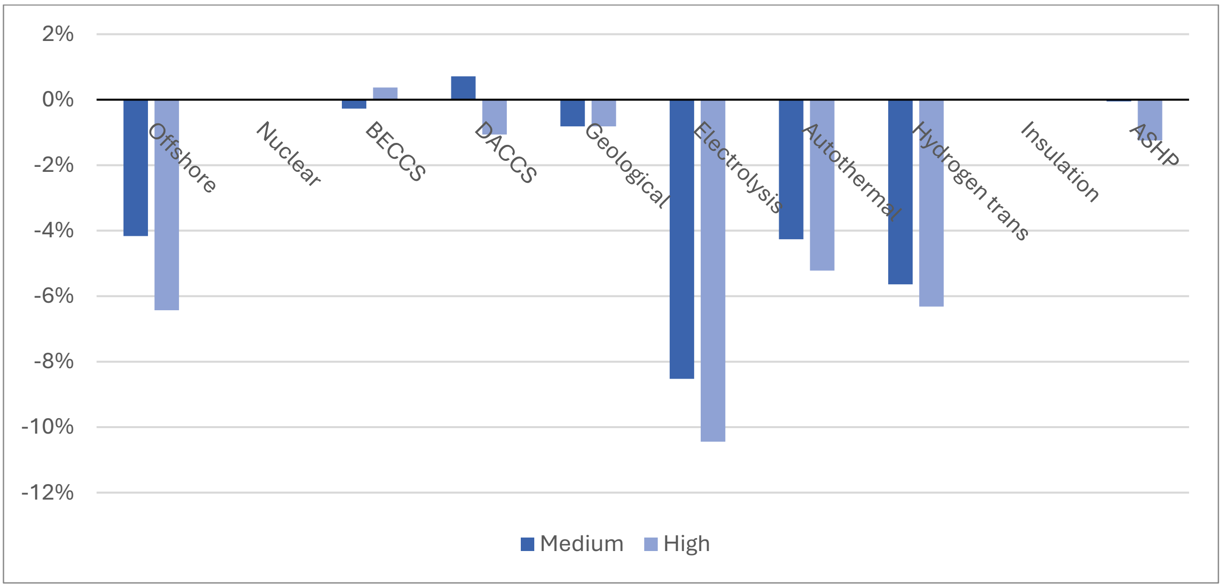

Figure 8: Impact of innovation in WSHP on generation of other technologies in 2050 compared to low innovation level run – Minimally Constrained scenario

Note – tidal, depleted gas field storage, gas-CCS, H2 turbines, and GSHP have all been excluded as their generation is either zero or too limited to provide meaningful comparison. Additionally, short and medium storage system modelling is performed using the HighRES model and so are also excluded. Data points for WSHP are also excluded as the 2-3 fold increase impacts the scale.

Disruptive technologies

This section highlights key findings from DESNZ-commissioned research into emerging and potentially disruptive technologies additional to the primary EINAs assessment. The purpose of the disruptive technologies research is to:

- Provide insight on emerging technologies outside of the core EINAs scope and explore the potential impacts of deployment on the future energy system; and
- Provide options for further exploration as a supplementary evidence base to inform prioritisation of future government support for clean energy innovation.

The selection of emerging technologies and summarised insights presented was informed by independent qualitative sub-sector analyses and targeted engagement with stakeholders in the academic community, industry, and government.

The technologies highlighted in this section serve as illustrative examples drawn from a long-list of emerging or alternative approaches with the potential to contribute to net zero if successfully deployed at scale.

This section provides an overview of the key findings into novel heating and cooling technologies including thermal energy storage approaches and solid state heat pumps.

Thermal energy storage

Table 6: Disruptive technologies: Thermal energy storage

Overview: Thermal energy storage (TES)	
Description of the technology	TES refers to a wide range of technologies that temporarily store energy in a material as a heat source or cold sink for later use. TES technologies can be divided into three main categories: **sensible heat (SH-TES), latent heat (LH-TES)**, and **thermochemical energy (TC-TES)** systems. Many TES systems are commercially deployed today but next-generation systems have greatly evolved in recent years. Application types vary widely across individual domestic houses, multi-user buildings, large commercial buildings, district heating, town and potentially regional thermal energy storage.[186]

[186] DELTA_EE_DECC_TES_Final__1_.pdf

Overview: Thermal energy storage (TES)	
Technology types[187]	**SH-TES** is the most commercially deployed TES type. SH-TES systems store thermal energy by increasing the temperature of a storage medium typically without changing its phase. Established SH-TES systems include water tanks storing thermal energy in the form of hot or cold water, and molten salt systems, currently used in concentrating solar power (CSP) plants, capable of storing high thermal energy for power generation during intermittency periods. **LH-TES** involves storing thermal energy through phase changes in materials, typically from solid to liquid or vice versa. The energy stored in **Phase Change Materials (PCMs)** is absorbed or released when the material changes its state. This capability, in addition to high energy density, makes PCMs, such as ice-water storage systems, particularly valuable for applications requiring stable temperature control. For example, in building heating and cooling systems, where the system can effectively shift energy use from peak to off-peak times.[188] **TC-TES** involves chemical reactions that absorb or release heat through reversible chemical reactions. This type of storage can achieve high energy density and is characterised by the potential for long-term storage with minimal thermal losses because the stored energy is held in chemical bonds.
Impact on the energy system	TES systems can store thermal energy during off-peak hours when electricity demand and prices are lower, and release it during peak hours. This load shifting capability can help to balance the grid and reduce peak demand. TES systems offer unique benefits, such as helping to decouple heating and cooling demand from immediate power generation and supply. The resulting flexibility allows far greater resilience on variable renewable sources, such as solar and wind power, helping to decarbonise the heating or cooling of buildings and industrial processes.[189] Additionally, by enabling the use of lower-cost electricity during off-peak periods, TES systems have the potential to provide to electricity cost savings for both residential and industrial users.

[187] Technology Strategy Assessment: Findings from Storage Innovations 2030 - Thermal Energy Storage. U.S. Department of Energy, July 2023.
[188] Current, Projected Performance and Costs of Thermal Energy Storage
[189] Thermal Energy Storage (TES) – Renewable Thermal Collaborative

Overview: Thermal energy storage (TES)	
Timescale	**SH-TES: TRL: 8-9** A range of sensible heat storage systems, such as water tanks, molten salt, and concrete, are well-established and widely used in both domestic and industrial applications and are considered mature technologies. **LH-TES: TRL: 5-6 (next-gen systems); TRL: 9 (basic systems)** Latent heat storage systems using more basic PCMs (water, salt hydrates, paraffin) are already at TRL 9 and are commercially available for use in various applications, including building materials and industrial processes. While basic systems are relatively mature, ongoing research aims to improve their efficiency and integration.[190] More advanced systems such as composite PCMs and nano-enhanced formulations aim to improve thermal conductivity or to be designed to better integrate within specific applications. Next-generation PCM systems are estimated to be between TRL 5-6 and expected to reach TRL 9 by 2030.[191,192,193] **TC-TES: TRL: 5-8** Thermochemical energy storage systems are advancing along the technology readiness spectrum, with developments ranging from laboratory-scale prototypes to near-commercial deployments. Whilst some systems, such as those under development by ZAE Bayern, have undergone pilot-scale demonstration (TRL 5–6).[194],[195] The RESTORE Project, funded under the EU Horizon 2020 programme, has demonstrated thermochemical energy storage (TCES) technology in operational environments for district heating and cooling, targeting TRL 8 by the end of 2025.[196] These advancements indicate growing maturity in the field, though further R&D and scaling are needed for widespread adoption.[197,198]

[190] SCE Design and Engineering Services
[191] Plentigrade - Phase Change Material (PCM) Technology - Sunamp Global
[192] Advances in Thermal Energy Storage Systems for Renewable Energy: A Review of Recent Developments
[193] Enhancing thermo-physical properties of hybrid nanoparticle-infused medium temperature organic phase change materials using graphene nanoplatelets and multiwall carbon nanotubes | Discover Materials
[194] ZAE Bayern – Services
[195] A Review of Thermochemical Energy Storage Systems for Power Grid Support
[196] Renewable Energy based seasonal Storage Technology in Order to Raise Economic and environmental sustainability of DHC | RESTORE | Projekt | Fact Sheet | H2020 | CORDIS | European Commission
[197] https://redoxblox.com/wp-content/uploads/2024/10/press-Redoxblox-Series-A-Release.pdf
[198] ITChES – Integration of ThermoChemical Energy Storage - SINTEF

Overview: Thermal energy storage (TES)	
Barriers	Advanced TES systems face several market entry barriers, including high initial costs and uncertain return on investment, which can deter potential adopters. Technological challenges such as ensuring performance reliability and integrating with existing HVAC systems further complicate deployment. Additionally, a lack of standardisation and regulatory hurdles for certification create uncertainty, while limited market awareness and education about the benefits of TES systems slow adoption. These issues are compounded by the need for scalable solutions that can be produced cost-effectively. Recycling, recovery and reuse of exotic chemicals also presents an area or uncertainty.

Overview: Thermal energy storage (TES)	
Key developers of the technology	(UK) Significant funding and support have been channelled into energy storage technologies through initiatives like the Longer Duration Energy Storage Demonstration competition (LODES). The LODES competition has funded a range of First-of-a-Kind (FOAK) TES developers:[199] (UK) The University of Edinburgh's Exergy3 project received funding to develop and prepare the test of a 36 MWh ultra-high temperature energy storage system that has the potential to significantly reduce the CO2 emissions of some of the most energy and carbon-intensive processes in the world. (UK) The University of Sheffield's ADSorB project received ~£2.5 million funding towards the development of the modular thermal energy stores and the control software and hardware, with prototype energy systems to be manufactured and deployed at the Creative Energy Homes campus at the University of Nottingham, enabling practical demonstration within lived-in homes. (UK) Sunamp has been working on enhancing the storage duration of their thermal batteries, integrating them with household energy systems to manage periods of low renewable generation effectively. Project EXTEND received ~£9.2 million funding to develop, build and trial the solution in 100 homes across the UK, evaluating the effects a fleet of thermal storage systems would have if a large number of them was deployed onto a specific area of the network. (USA) Co-led by NREL, Stor4Build is investigating new TES materials and systems that can level out peak energy demand, thereby reducing grid outages and enabling more cost-effective electrification of buildings. (Europe) The Swedish energy storage company SaltX Technology focuses on innovative energy storage solutions, including thermochemical storage using salt-based materials for both industrial and residential applications.[200] (Europe) Research is also focusing on novel materials and configurations for TES to improve its adaptability and efficiency in buildings. This includes developments in phase change materials and sorption systems, which are being tailored for high-efficiency, autonomous buildings that aim to be energy-independent.

[199] Longer Duration Energy Storage Demonstration Programme, Stream 2 Phase 1 projects - GOV.UK
[200] SaltX Berlin pilot plant shows very promising results - SaltX Technology

Overview: Thermal energy storage (TES)	
Sectoral impacts and links to priority EINAs technologies	
Renewables	TES can aid with balancing the intermittency of renewable energy sources such as solar and wind by storing excess energy produced during peak times and releasing it during demand peaks. This capability reduces reliance on fossil fuels and enhances grid stability.
Heating and buildings	As the UK shifts from gas to greater use of electricity-based heating systems to meet Net Zero targets, TES can reduce peak load demands on the electricity grid. TES can also improve the energy efficiency of buildings, helping to reduce overall energy consumption and operational costs, e.g., through thermal storage to offset cooling demand through nighttime cooling.
Smart systems	Integrating TES into the electricity grid can enhance its stability and flexibility, allowing for better management of energy supply and demand, and facilitating integration of renewable energy sources.

Solid state heat pumps (SSHPs)

Table 7: Disruptive technologies: Solid state heat pumps

Overview: Solid state heat pumps (SSHPs)	
Description of the technology	Solid state heat pumps (SSHPs) that can deliver heating, cooling or both diverge from conventional systems that rely on compressors and refrigerants and instead use solid state effects to generate heat / cool. SSHP technologies proposed for heating and cooling include: elastocaloric (using stress-induced temperature changes), magnetocaloric (using magnetic fields), electrocaloric (using electric fields), barocaloric (using pressure changes), thermoelectric (converting temperature differences into electric voltage and vice versa) and mechanocaloric (using pressure or stress). These systems have shown potential for significant environmental advantages by eliminated the need for refrigerants and reducing energy consumption due to high efficiencies. These systems have the potential to be highly efficient, compact, with few moving parts and do not contain environmentally harmful or combustible refrigerants. They can

Overview: Solid state heat pumps (SSHPs)	
	also be easily configured in different shapes and sizes to meet demands.
Impact on the energy system	As global emphasis on sustainability increases, solid state heat pumps are poised to replace traditional systems, providing energy-efficient and environmentally friendly alternatives for residential and commercial buildings. Beyond buildings, solid state technologies have potential applications in industrial processes that require precise temperature control. Industries focused on high-tech manufacturing, such as semiconductors and pharmaceuticals, could benefit significantly.
Timescale	The development stage of SSHPs is mixed with most currently estimated at TRL of 4-6, with potential to reach TRL 7-8 by 2035 at the earliest. However, early entrants to the market include Anzen who are trialling heat pump solutions for homes and Camfridge who offer magnetic refrigeration solutions currently at higher TRL.
Barriers	The deployment of SSHPs faces several barriers, including the high cost and durability of caloric materials used in SSHP systems, competition from established technologies like traditional heat pumps, and the challenge of identifying the most promising SSHP options among various solid state effects. Disrupting the mature commercial market requires commercial and technical development to reduce costs. Integrating solid state technologies into existing building infrastructure and scaling these solutions to larger applications presents engineering and logistical challenges that require further innovation in system designs and compatibility solutions. The regulatory landscape needs to keep pace with technological advances to facilitate the adoption of SSHPs. Market penetration strategies also need to address the inertia of established industries and consumer awareness.
Key developers of the technology	RES4BUILD, a Horizon 2020 project, is developing integrated systems that can be controlled via the internet of things (IoT) for magnetocaloric heat pumps to optimise energy consumption and performance in real-time.

Overview: Solid state heat pumps (SSHPs)	
	US Department of Energy (DOE) is funding research and development projects aimed at enhancing the efficiency and reducing the costs of solid state technologies. University of Cambridge, Grant Instruments, and Evonik (Germany) have received EPSRC funding of ~1.4 million to develop barocaloric SSHPs. The project also includes developing economic and policy strategies to support the development and commercialisation of barocaloric heat pumps. Sunamp has received Horizon Europe funding of ~£260,000 to develop MolCal research group focusing on caloric materials and energy conversion technologies for solid-state cooling and heating applications at near-ambient and very-low temperatures. Thermoelectric Conversion Systems (TCS), a UK based startup focused on commercialising thermoelectric technologies for heating and cooling applications, has announced an Early Adopter Programme (EAP) for its core technology.
Sectoral impacts and links to priority EINAs technologies	
Heating and buildings	Deployment of SSHPs can significantly displace the use of refrigerants often which have a GWP. They also offer an alternative to low GWP refrigerants which can be toxic and flammable gases. SSHPs therefore enhance public health and safety. They can also be configured in different formats and sizes making new ways of applying in new and retrofit applications.
Smart systems	SSHPs can be integrated into smart grids, allowing for dynamic energy management and improved demand response. This integration can potentially help balance load, enhance grid stability, and facilitate the increased use of renewable energy sources.

Market innovation barrier and enabler deep dives

As part of the EINAs project, a simplified barriers and enablers assessment was carried out across the prioritised technologies to understand the factors which should be considered for each technology in addition to technology innovation. This included qualitative analysis across eight variables, as detailed in below, which includes a low/medium/high rating for each element to indicate the relevance and risk of each barrier to the deployment and scale up of the technology. The eight variables assessed were:

- **Enabling infrastructure:** There are well established supply chains for roof insulation, but significant barriers to application of solutions for wall and floor insulation to UK building stock. For heat pumps, the electric grid capacity is a significant constraint for areas in the UK, particularly for the decarbonisation of the existing buildings stock.
- **Regulatory environment:** Regulatory support (e.g. building regulations, government and energy supplier funding) and few regulatory barriers for roof and floor insulation, but barriers for wall insulation, e.g. planning policies. Current building regulations do not actively promote the uptake of heat pumps, but the regulations now under consultation (Future Home Standard) are proposing to address this.
- **Stakeholder acceptance:** Varying levels of stakeholder acceptance for insulation, from high for roof but low for wall. Primarily in the domestic sector, heat pumps are perceived as more difficult to install and use, have a high cost, and there is a lack of awareness about the technology.
- **Availability of funding and investment:** Varying levels of funding available for insulation, from high for roof but low for wall. For heat pumps, the domestic market in UK should have a higher level of investment / R&D given expected scale.
- **Business model viability:** Low cost and high level of consumer understanding for roof insulation makes business model viable, but this is disrupted for wall and floor insulation where the disruption and consumer appetite has an impact. Particularly for domestic users, current capex of heat pumps is very high and whilst additional financial models have been explored, they are not mature.
- **Resource availability:** Generally existing trades and supply chains and extensive opportunity for DIY installation for insulation. No major barriers for heat pumps.
- **Supply chain:** Large existing supply chains for roof insulation, but lower for wall and floor. For heat pumps, the UK has a well developed supply chain for the technology, made up of domestic manufacturing and imports, but will need to further expand in the coming decade to meet +1m yearly installations suggested by EINA modelling. .
- **Skills and training:** Mature training and competency framework for roof insulation but training still not commensurate with technology risk level for wall and floor. For heat

pumps, there has been significant growth in the workforce, with around 9,000 individuals taking heat pump training in the UK in 2024.[201]

This section summarises and expands on the key barriers and enablers for the hydrogen energy technologies, which can be considered alongside the priorities for technology innovation.

Deep dive 1: Financial proposition to consumers (heat pumps)

One of the main barriers to heat pump deployment has been the financial proposition to consumers relative to gas boilers, which is the incumbent technology.

Currently heat pump upfront costs, enabling works and operational costs contribute towards a challenging financial proposition to consumers. The upfront cost of buying and installing a heat pump impacts affordability, especially when additional costs required to improve fabric performance in homes can be required to limit peak electricity demand and improve efficiency in existing UK domestic stock. In addition to this, the current consumer journey can be fragmented, lengthy, and complex, which leads to increased costs and a high number of dropout points.

An unappealing financial offering and customer journey for consumers can lead to a low heat pump uptake, which means that the current UK energy market could struggle to meet key milestones in heat pump deployment numbers required to be net zero by 2050. A low uptake can also in turn lead to a diminished ability for the heat pump supply chain to reduce costs as it cannot reach economies of scale.

A range of policy solutions that address cost barriers has already either been adopted or is currently being reviewed. Such solutions include limiting upfront costs through governmental grants, tax rebates, as well as reducing operating costs by rebalancing electricity and fossil fuel taxes. Increased financial support from the 'Boiler Upgrade Scheme' has greatly reduced the CAPEX required for installation and improved number of applications, but long-term challenges remain, with more support required to strengthen the current financial offering.

Policy has also been put in place to address some of the cost barriers by supporting the development of more cost-efficient design and installation solutions. DESNZ has invested a total of £25 million to develop solutions that help improve the ease of heat pump installations in homes through the 'Heat Pump Ready Programme'.[202] Additional consideration can be given to reducing the cost for enabling works and additional infrastructure required for GSHP and WSHP installations, as well as future connectivity to heat networks for these technologies. Challenges for these technologies include for example that as opposed to the previous Renewable Heat Incentive (RHI) approach, the current 'Boiler Upgrade Scheme' does not recognise the higher CAPEX required for the installation of GSHPs, with the same grant allocated for ASHP, GSHP and WSHP.

[201] Heat Pump Association (2025) Statistics - Heat Pumps
[202] UK Government (2023) Information about the Heat Pump Ready Programme

It is expected that there should be also opportunity for the development of market driven financial offerings, for example through energy supply companies. These offerings can be based on “one-stop-shop” models such as Heat-as-a-Service (HaaS) and Energy as a Service (EaaS). These services could allow a single point of use model, delivering one point of contact for consumers for financing, design and support and looking to overcome consumer barriers such as cost (upfront and ongoing), information asymmetry and improve the consumer journey.

There has currently been only limited commercial deployment of the EaaS and HaaS models. These are however being looked at through small scale trials, such as the E.ON Green Home Finance Accelerator project, which focusses primarily on EaaS, or programmes such as The Green Home Finance Accelerator, which funded the development and piloting of green finance products and services which can enable uptake of home energy efficiency, low carbon heating and micro-generation retrofit measures. [203, 204]

Other financial instruments such as Property Linked Finance (PLF) are also expected to be explored to support homeowners access affordable funding for environmental improvements by linking the finance to the property instead of the owner. [205]

Once new financial offerings are stable, these domestic capabilities can be applied to international opportunities and expansion through exports and services, enhancing the UK’s future competitive positioning in the energy transition market.[206]

Deep dive 2: Supply chain (heat pumps)

The heat pump supply chain is comprised of Tier 1 manufacturing (manufacturing and assembly of the final heat pump unit), Tier 2 manufacturing (heat pump components) and companies covering the design, sale, distribution, installation, commissioning (and decommissioning), maintenance and repair of the units.

The UK has currently a limited domestic heat pump Tier 1 manufacturing sector, meeting approximatively 30% of the UK market demand.[207] In addition to the low proportion met domestically, the UK market is also relatively small compared to other European countries and has had a lower growth rate than anticipated in Net Zero pathway projections. The National Audit Office (NAO) reported that the number of heat pump installations by December 2023 was less than half of planned projections, uncertainty which hampers the development of the domestic supply chain. In addition to the low demand, pressures in the global supply chain of semiconductors, which are a key heat pump component, and high energy prices increasing

[203] E.ON (2024), Green Finance Accelerator Discovery Phase Evidence Report: E.ON’s Optimised Energy as a Service
[204] DESNZ (2025) Green Home Finance Accelerator: Discovery Phase projects
[205] Green Finance Institute (2024), A greenprint for Property Linked Finance in the UK
[206] PWC (Accessed: 2025) Looking Ahead – Future Market and Business Models
[207] BEIS (2020) Heat pump manufacturing supply chain research project report

manufacturing costs are also factors that contribute to the lag in development of the UK local supply chain.[208]

A developed and mature local and international supply chain can play an important role in reducing the upfront cost of heat pumps, which could then positively impact demand and uptake in the market. In order to meet heat pump deployment targets, the supply chain will need to be supported for growth across different areas, predominately focused around the provision of confidence in the long term increase in demand for heat pumps in the UK, which would lower manufacturer's risk and improve the return on investment, but also financial support for establishing manufacturing facilities and innovation funding for items with value added for the UK, such as energy market flexibility.[209] The supply chain's ability to respond to demand with the appropriate support in place is also acknowledged by the Heat Pump Association in its recent supply chain readiness report.[210]

As opposed to Tier 1 manufacturing, Tier 2 manufacturing for components is already well established internationally and it has been noted that development barriers to entry in the UK are likely to make its domestic development challenging.[211]

Government bodies play and have played an important role in establishing a steady local supply chain. For example, DESNZ is currently exploring ways to make heat pump more affordable through the 'Electrification of Heat Task Group'. The second round of the 'Heat Pump Investment Accelerator Competition' has also been announced, which will provide up to £90 million funding to increase the domestic manufacturing rate of heat pumps by up to 410,000 per year by 2030. The aim is to reduce costs by lowering dependency on imports and supply chain delays. It also recognises that the current house-by-house delivery model will be kept under review, as some stakeholders have suggested a street-by-street approach will be most efficient.[212]

As the entire heat pump supply chain is developed in the UK, the substantial transitional growth opportunities to reuse the existing boiler supply chain will need to be harnessed improve domestic supply chain flexibility and resilience. Opportunities to reskill the existing workforce, such as the Heat Training Grant, are needed to leverage existing supply chains and build on the experience from boiler to heat pump manufacturing based on the existing domestic presence of the UK boiler manufacturers.

Deep dive 3: Skills and training (heat pumps)

The installation market in the UK is fragmented as it is generally characterised by small companies or sole traders.[213] In 2021, the 'Business, Energy and Industrial Strategy

[208] NAO (2024) Decarbonising home heating
[209] DESNZ (2020) Heat pump manufacturing supply chain research project report
[210] HPA (2025) Heat Pump supply Chain Readiness to deliver Net Zero Homes
[211] DESNZ (2020) Heat pump manufacturing supply chain research project report
[212] NAO (2024) Decarbonising home heating
[213] DESNZ (2020) Heat pump manufacturing supply chain research project report

Committee' and 'Environmental Audit Committee' highlighted a skills gap in the sector, where workers do not have the expertise to install the required scale of low-carbon heating.[214]

The fragmented and limited number of installers slows the diffusion of installation best practice and standardisation, as well as reduces cost transparency and increase lead time for heat pump installations.[215] To enable a better transition to decarbonising heat in buildings, the government and the leading manufacturers play an important role in increasing the number of installers and professionals who can maintain existing systems, providing them with an installation pipeline and reducing the installation skills gap within the sector. Training initiatives have helped address such challenges and supported increased deployment in the past years[216], however an increased number of trained individuals will be needed to meet +1m yearly installations suggested in EINAs modelling.

DESNZ is currently mitigating the risk of poor installation by requiring Microgeneration Certification Scheme (MCS) certified heat pump installation funded through government schemes such as the Boiler Upgrade Scheme. However, only 17% of employers that offered heat pump installations were part of the MCS scheme[217]. Furthermore, the £10 million Heat Training Grant supports trainees in England taking training relevant to heat pumps and heat networks[218]. In April 2025, DESNZ announced a £5 million extension of the scheme for this financial year, bringing the total value of the grant to £10 million. This will support around 5,500 professionals to upskill to become heat pump installers.[219] Training, such as the Refrigerant Driving License by United Nations Environment Programme (UNEP), are further examples of schemes that can be provided to minimise accidents and ensure safe handling of refrigerants.[220]

The UK can benefit both economically and environmentally from improving the current heat pump installation and systems maintenance workforce through increased awareness of suitable and cost-effective training, including training subsidies. An improvement to the current workforce will facilitate job creation within the local economy and build consumer confidence through successful installations across the UK, supporting heat pump uptake.

The development of the installation and systems maintenance workforce will need to and is being supported through innovation solutions that seek to simplify the installation and product maintenance process. For example, projects part of the 'Heat Pump Ready Programme: Stream 2 Wave 2' are looking at digital solutions such as the HomelyLifetime, which will provide an installed portal with proactive insights for improved maintenance. Such solutions will support upskill and improve the overall effectiveness of the installation workforce.

[214] NAO (2024) Decarbonising home heating
[215] Nesta (2022) How to Reduce Cost of Heat Pumps
[216] Heat Pump Association (2024) Projecting the Future Domestic Heat Pump Workforce
[217] DESNZ (2023) Heating and Cooling Installer Study (HaCIS)
[218] NAO (2024) Decarbonising home heating
[219] DESNZ (2025) Heat Training Grant: heat pump scheme review
[220] IEA (2022) The Future of Heat Pumps

Deep dive 4: Installation (Insulation)

High quality insulation installations have the potential to enable significant societal and economic benefits, beyond carbon reduction. Successful installations should create healthier and safer buildings, and boost wellbeing, productivity and climate resilience. However, there are barriers to increasing and improving insulation in buildings, chiefly cost barriers for new build and retrofit and disruption to occupants for retrofit projects.[221] The increasing costs of insulation materials, combined with grid decarbonisation and the relative costs of gas and electricity has disincentivised further improvements to insulation standards in UK Building Regulations:

'Grid decarbonisation also means that fabric improvements are increasingly not a cost-effective intervention to reduce carbon. This means that as we increase fabric beyond the proposed level, the monetary value of carbon saved by increasing fabric efficiency is less than the cost of installing that additional fabric. As such, there are other interventions that decrease carbon and consumer bills in a more cost-effective way, such as (above) switching heat source and including solar PV panels.'[222]

The scale of failure of previous insulation schemes in the UK is now well documented. Action is being taken to address some past failures, through the Building Safety Act, Awaab's Law, the Warm Homes Plan and a select committee hearing on retrofit failures (February 2025).[223, 224, 225, 226, 227]

The evidence above suggests that building insulation is a relatively mature technology and that existing insulation technologies, along with clean heating, should be sufficient in enabling the transition to low carbon buildings. However, the evidence also points to a need for innovation in the approaches for deploying existing insulation technologies cost-effectively, at scale and to high quality standards. This is necessary to maximise the wide-ranging benefits of insulation and to avoid costly unintended consequences, such as increasing fire risk, introducing damp, mould or decay.

Potential topics for research, development and innovation to increase the likelihood of successful, scaled up deployment of existing insulation technologies include:

- Collaboration across all policy areas impacted by widespread insulation deployment. The connections between well-insulated, well-ventilated homes and better health outcomes are well documented, as is analysis of the potential associated economic impacts (job creation etc.) and benefits to energy flexibility, energy security and climate resilience. Lack of access to warm, dry housing as a factor contributing to other issues

[221] IEA (2023) Net Zero Roadmap: A global pathway to keep the 1.5 goal in reach
[222] Department for Levelling Up, Housing & Communities (2024) The Future Homes and Buildings Standards: 2023 consultation - GOV.UK
[223] UK Government (2025) Action taken to protect households with poor-quality insulation
[224] UK Government (2024) Help to save households money and deliver cleaner heat to homes
[225] UK Government (2025) Awaab's Law to force landlords to fix dangerous homes
[226] UK Government (2022) The Building Safety Act
[227] UK Parliament (2025) Retrofit failures: How do we move forward on warm homes?

such as youth violence, school attendance and productivity is less well documented but highly relevant. Taking an integrated approach across multiple policy areas could identify opportunities to streamline delivery efforts and costs, pool budgets and resources, share knowledge, avoid duplication, accelerate action and track progress and outcomes.

- Quality control for insulation deployment. Past failures indicate that there is potential to improve quality standards throughout the insulation installation process, from the methods for identifying appropriate buildings - and households - for fabric retrofit measures, to insulation design, installation and maintenance. Addressing weak spots in quality management interventions across existing policy, regulation, standards, accreditation and training provision could help to de-risk future insulation deployment.
- Comparing insulation schemes with low and high failure rates. Analysing past and current retrofit schemes could help to identify critical differences in delivery, best practice approaches and identify further opportunities for innovation e.g. reviewing works undertaken via the Social Housing Decarbonisation Fund, the Energy Company Obligation scheme and the Great British Insulation Scheme.
- Approaches to inspire and support the retrofit workforce. Consider methods for creating an engaging and supportive work environment through continuous training/development, mentorship, access to resources and reward system to develop employees’ skills and improve retention.

Business opportunities in heating and buildings

Introduction

The purpose of this section is to explore the potential scale of the business opportunities for the UK associated with the national and global development of the heat and buildings sector, as elsewhere in this report defined as insulation (roof, wall & floor), ASHPs, GSHPs and WSHPs. Innovation will be a key driver in supporting the growth of this sector in the UK and realising these business opportunities, and therefore an important element to capture as part of this innovation assessment.

The section summarises the key findings from the development of a series of ‘business opportunities calculators’. These calculators integrate projections of domestic deployment of the three technologies, derived from scenario-based systems modelling (see Heat and buildings innovation opportunities) with assessments of the UK’s potential market share in overseas markets, informed by global modelling and literature reviews. They combine this understanding of potential deployment with assumptions around the cost structure and employment intensity of the different activities required for the manufacturing, deployment and operation of each technology to generate an understanding of the potential business opportunities in terms of:

- Gross Value Added (GVA) – a measure of the value generated by the production of goods and services. GVA can be thought of as broadly equivalent to the contribution of that sector/activity to Gross Domestic Product.
- Employment – Employment is measured in terms of jobs and includes both direct employment – the jobs associated with the construction, operation and decommissioning of the assets – and indirect employment – the jobs associated with the production of the goods and services needed by the workers with direct jobs i.e. jobs associated with the supply chain needed to construct, operate and decommission the assets.

All results are illustrative of potential business impacts of technological innovation. They are generated using a particular set of technologies, hypothetical deployment scenarios, modelling outputs and other assumptions to help inform UK Government decision making.

The modelling outputs on which the results are based include modelled expectations for deployment in both 2020 and 2025. While efforts have been taken to calibrate these modelled outcomes with existing deployment data, some inconsistencies will remain.

It is also important to stress that the results are specific to the particular technologies of focus for the report, rather than the GVA and employment for the wider sector within which these technologies may often be categorised. As such, care should be taken when comparing the figures presented below with estimations which cover the entire sector and use different scenarios and models.

Results do not reflect UK government targets or ambitions for either deployment or the business opportunities that might be realised. All monetary values in this section refer to 2022 GBP unless otherwise specified.

Heating and buildings market landscape

UK market position

As discussed earlier in this report, insulation technologies are already widely used in the UK both in new builds and to retrofit the nation's aging housing stock. Initiatives like the Great British Insulation Scheme (GBIS) aim to retrofit hundreds of thousands of homes, driving energy efficiency and progress toward net zero targets. Consistent with this, the ONS Low Carbon and Renewable Energy Economy survey suggests that the turnover of UK-based businesses involved in the supply of energy efficiency products (including insulation, alongside other products[228]) grew to approximately £15 billion in 2022, about 18% higher than in 2015. The corresponding direct employment associated with these businesses is around 82,000, although this has fallen from 91,000 in 2015.

The UK's heat pump market remains small relative to European comparators like France and Germany, with 98,000 units sold in the UK in 2024[229] as compared to the 720,000 and 437,000 sold in France and Germany respectively.[230] The UK market has however been growing in recent years with the turnover of UK-based businesses associated with the renewable heat sector growing from around £350m in 2015 to £2.4 billion on 2022 (a compound annual growth rate (CAGR) of 32%) according to ONS.[231] Similarly, direct employment in the sector has risen to around 15,000 in 2022, at a CAGR of 29% (since 2015)[232]. Looking forward, a 2020 DESNZ report estimates that the UK will manage to reduce its reliance on imports from 67% in 2020 to just 34-45% of the market by 2035.[233]

Global heating and buildings market

This positioning puts the UK in a strong position to capture a material share of what is expected to be a rapidly growing global market, particularly for heat pump technologies.

- **Insulation**: The forecasts for the size of the global insulation markets for each insulation type are based on projections by Dataintelo, a market research company. They have

[228] In the ONS data, this grouping also includes, for example, energy efficient doors and windows; heating and ventilation technologies; energy efficient building materials; sustainable buildings and architecture. See ONS (2024) Low Carbon and Renewable Energy Economy (LCREE) Survey QMI
[229] Heat Pump Association statistics https://www.heatpumps.org.uk/resources/statistics/
[230] Ehpa (2024) European Heat Pump Market and Statistics Report 2024
[231] Office for National Statistics (2024) Low carbon and renewable energy economy UK: 2022
[232] In the ONS data, the renewable heat sector covers all businesses involved in the design, production, and installation of infrastructure for generating heat directly through solar, thermal, geothermal or other means, including operations and maintenance.
[233] Department for Business, Energy and Industrial Strategy (2020) Heat pump manufacturing supply chain research project

forecasted the value of the roof, wall and floor markets until 2032 and, for this analysis, it is assumed that the CAGR they forecast for that 10-year period can be extrapolated until 2050.[234][235][236] Their forecast in terms of market value (USD) is first converted into GBP and adjusted for the percent of buildings energy demand which is residential (70%).[237] The resulting series for the global market value of residential insulation, in GBP, is then converted into series of annual additions of energy saving capacity (TWh) using the UKTIMES outputs for capital costs per TWh of energy saving capacity (£/TWh). This method leads to the following forecasts:

  - **Roof:** 320 TWh of additional energy saved per year through roof insulation by 2050.
  - **Wall:** 428 TWh of additional energy saved per year through wall insulation by 2050.
  - **Floor:** 235 TWh of additional energy saved per year through floor insulation by 2050.

- **Heat pumps:** IEA (2021) forecasts that there could be 1.8 billion heat pumps worldwide in a Net Zero 2050 scenario.[238] The IEA also forecast that roughly 70% of buildings energy demand is residential and this analysis assumes that this proportion also holds true for buildings energy demand from heat pumps. Combining these two forecasts, and assuming that the global distribution of heat pump technologies matches that seen in the EU, and that this distribution remains the same over time, leads to the following projections for global domestic heat pump capacity[239]:
  - **ASHP:** 7,929 GW of ASHP capacity by 2050.
  - **GSHP:** 605 GW of GSHP capacity by 2050.
  - **WSHP:** 44 GW of WSHP capacity by 2050.

Building on this discussion, the quantitative analysis below assumes that the UK can service the majority of its domestic market in these technologies, while also accessing some of the global export market. The analysis of market shares varies slightly between technologies. The shares for insulation technologies are based on those used in previous Energy Innovation Needs Assessment (EINA) studies; it is assumed that UK-based firms could capture approximately 4–5% of the global market, while securing between 70-100% of the market associated domestic deployment of these technologies. For heat pumps, previous analysis conducted by Ricardo for DESNZ using GEM-E3 modelling suggested that UK-based businesses will be able to capture between 65% and 69% of the domestic market and 0.5% of the global market.[240] This relatively low global market share reflects that exports are expected to be challenging due to different regulations and the prevalence of different heat pump

[234] Data Intelo (2025) Roof Insulation Market
[235] Data Intelo (2025) Wall Insulation Market
[236] Data Intelo (2025) Floor Insulation Market
[237] IEA (2021) Net Zero by 2050: A roadmap for the global energy sector
[238] ibid.
[239] Eurostat (2025) Heat pumps - technical characteristics by technologies
[240] The 2024 Ricardo report is title *"Research to quantify the economic opportunities for the UK as a result of the global energy transition"*.

technologies in different markets. European countries with similar climates and growing markets such as Ireland and the Netherlands could provide the most promising avenues for market capture.[241]

Heating and buildings business opportunity analysis

Gross Value Added (GVA)

The business opportunities calculators suggest that, assuming a 'medium' level of innovation, GVA in the heat and buildings sector, for the technologies included in the EINAs analysis (heat pumps and building insulation) will grow strongly in all the scenarios modelled. Figure 9 shows that real GVA grows from around £0.9 billion in 2025 to between £5.2 and £5.7 billion in 2050, depending on the scenario. While the GVA at the start and end of this time horizon is quite similar across the scenarios, the path in the High Diversification scenario is very different from the other two scenarios. In this scenario there is a surge in the uptake of wall and floor insulation between 2030 and 2040, which is not seen in the other scenarios. In 2035, in this scenario, wall insulation contributes £2.4bn in GVA (35% of the total in this year) and in 2040, wall and floor insulation contribute £3.9bn and £1.5bn in GVA respectively (40% and 15% of the total in this year respectively). By contrast, over the same time period, there is very little contribution from these technologies in the other scenarios.

The other four technologies follow a roughly similar pattern across all scenarios with an accelerated build up between 2025 and 2035 with a CAGR of GVA of around 20%, followed by a slower rate of growth after 2035.

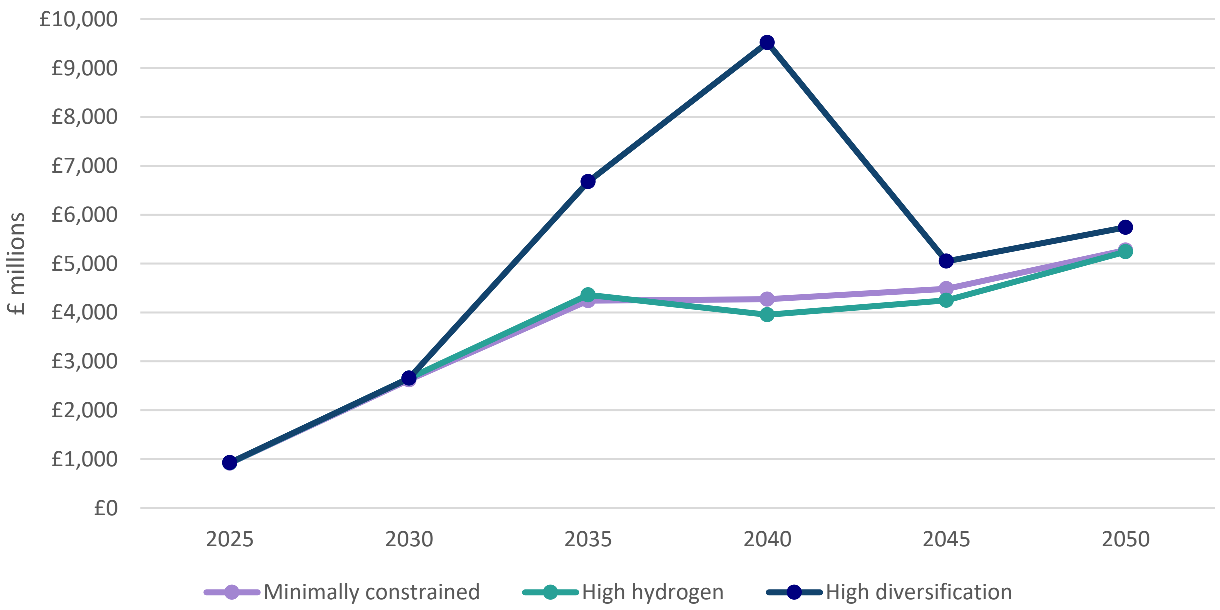

Figure 9: GVA by scenario for EINAs selected heating and building technologies *(based on* medium level of innovation)

[241] Social Market Foundation (2023) Supply change: Seizing opportunity in the UK heat pump supply chain

As Figure 9 shows, the calculators suggest that GVA in the sector will be largely dependent on the domestic market but that the export sector will become increasingly important by mid-century. In the Minimally Constrained and High Hydrogen scenarios the size of the domestic market is expected to remain relatively stable between 2035 and 2050 with GVA ranging from between £2.7bn to £3.4bn over the period in both scenarios. This represents around 75-76% of total GVA in 2035 but only 64% of total GVA in 2050 as exports grow in importance. In the High Diversification scenario, the large domestic uptake of wall and floor insulation between 2030 and 2040 leads to a significantly higher GVA contribution associated with supplying the domestic market, averaging at around £3.5bn per year for those technologies alone. For this scenario, in these years, the domestic market is expected to account for around 84-87% of total GVA. This is due to large scale deployment of insulation measures over 2030-2040 caused by higher reliance on domestically sourced energy and a more diversified generation mix in the High Diversification scenario. However, by 2050, the domestic market in this scenario is expected to contribute to around 67% of GVA, in line with the other scenarios for that year.

The consistent rate of growth of GVA from exports at the aggregate level is driven by exports related to ASHPs and the three insulation types. GVA from exports related to insulation are expected to grow with a CAGR of 6% between 2025 and 2050 with GVA from ASHP related exports expected to have a CAGR of 3% over the same period. Exports related to GSHPs and WSHPs remain relatively modest across the period.

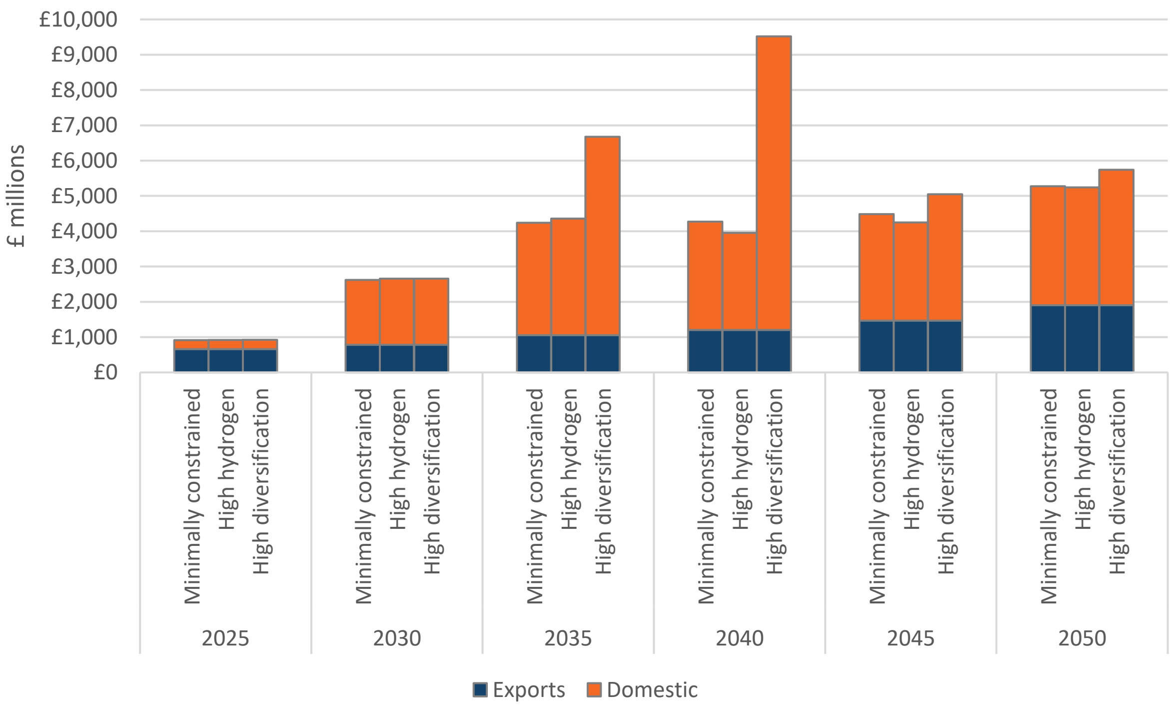

Figure 10: GVA by scenario by market for EINAs selected heating and building technologies
Note: The figure reports outputs associated with a medium level of innovation.

Figure 11 shows that, after 2030, there is substantial variation in the GVA contribution between innovation levels in all three scenarios. Across the scenarios, GVA is typically lowest in the medium innovation scenario. The reason for the counterintuitive result that low innovation is associated with higher levels of GVA than medium innovation is due to the relationship between costs and economic activity. All else being equal, goods and services that have higher costs, provided they continue to be purchased, are associated with the value of those goods and services being higher i.e. that the activity leading to those goods and services makes a higher GVA contribution. The lower costs in the medium innovation level compared to the low innovation level do not lead to a sufficiently large increase in deployment of the technologies to offset this effect.

Comparing the high and low levels of innovation, in many cases a higher level of innovation is associated with a higher GVA contribution. This is evident, for example, in all scenarios in 2045 and in the Minimally Constrained and High Hydrogen scenarios in 2035 and 2040. This is intuitive. The key scenario where this order is reversed is in the High Diversification scenario for 2035 and 2040, where the increase in use of wall and floor insulation suggested in the systems modelling dominates any variation in use due to differences in innovation. In this case, the effect described above - that, all else being equal, high costs increase the measured value of goods and services as long as they continue to be purchased - means that the GVA contribution is highest at the low level of innovation. Likewise, the GVA contribution in the low innovation scenario results in the highest GVA contribution in all three scenarios in 2050.

The potential impact that higher or lower costs may have on the output, and hence GVA contribution, of other sectors in the economy is not captured in this analysis.

Figure 11: GVA by scenario by innovation level for low, medium and high innovation levels for EINAs selected heating and building technologies

Figure 12 shows that in the scenarios modelled, for the ‘medium’ innovation level, ASHPs make the largest contribution to GVA in most years. In 2040, the second largest contributor is typically WSHPs used in heat networks, which contributes around 11% of total GVA at that point. The exception to this is the High Diversification scenario where, as previously discussed, the substantial deployment of wall insulation between 2030 and 2040 means that this technology makes the largest contribution to GVA in 2040. By 2050, wall insulation surpasses WSHPs as the second largest contributor to GVA in the sector. ASHPs relative importance remains steady over the period for all three scenarios from roughly 70% in 2040 to around70% in 2050 for Minimally Constrained and High Hydrogen scenarios but increases from 29% to 61% over the same period for High Diversification. Outside of the High Diversification scenario, the modelling suggests that heat pumps will be a much larger market opportunity than insulation with the three heat pump technologies accounting for 78% of total GVA in 2050.

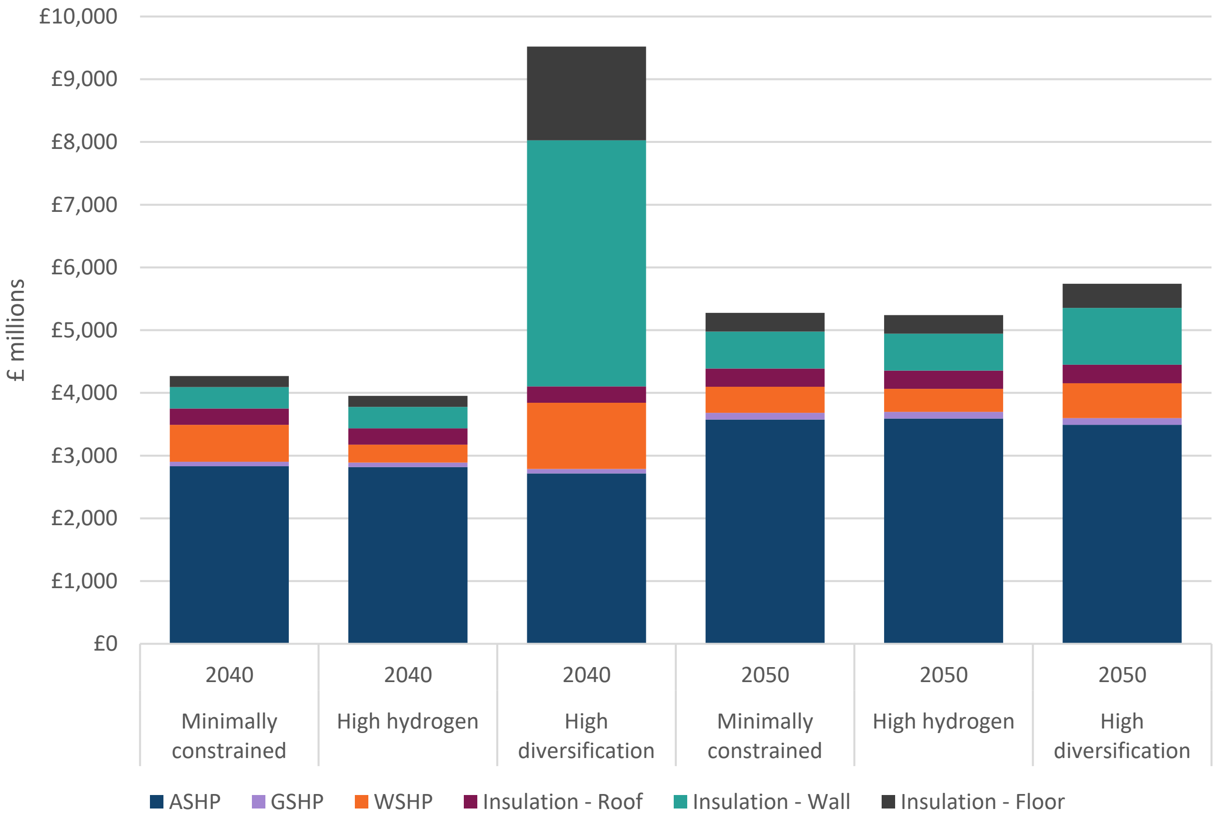

Figure 12: GVA by scenario by technology for EINAs selected heating and building technologies (based *on* medium level of innovation)

Direct and indirect jobs

Supported employment (direct and indirect jobs[242]) follows the patterns in GVA. Across all the modelled scenarios, supported employment increases from around 25,000 jobs in 2025 to between 170,000 and 183,000 jobs in 2050. This represents a CAGR in supported

[242] A direct job is employment associated with the stated activity. An indirect job is a job that exists to produce the goods and services needed by the workers with direct jobs i.e. those jobs associated with supply chain activities. The estimate of indirect jobs is based on the application of Type 1 multipliers to the different cost categories (activities) within the sector.

employment of around 8%. In the Minimally Constrained and High Hydrogen scenarios, the number of jobs peaks in 2050, while in the High Diversification scenario there is a spike in employment between 2030 and 2040 due to the previously described surge in wall and floor insulation deployment. In the High Diversification scenario, there an additional 64,000 and 146,000 jobs in wall and floor insulation in 2035 and 2040, respectively, compared to the Minimally Constrained and High Hydrogen scenarios. Over the whole period and in all scenarios, 49-54% of the total jobs are direct jobs, which means that roughly one additional indirect job is expected for each direct job.

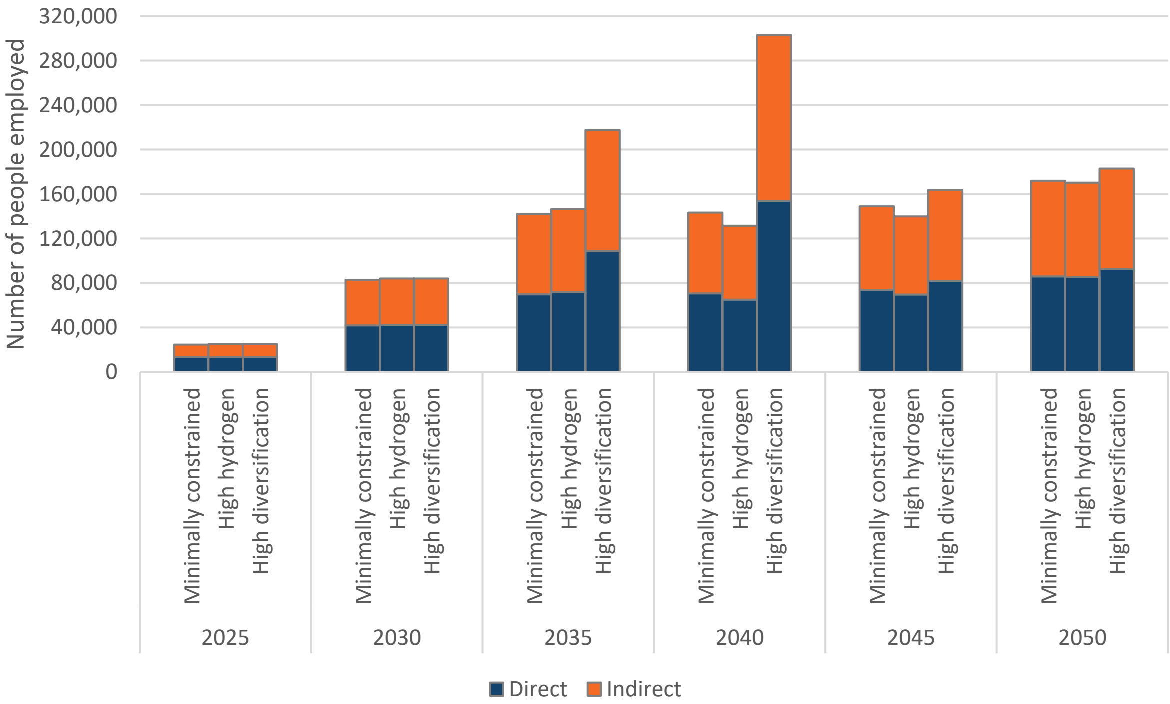

Figure 13: Total jobs supported by scenario by direct vs indirect for EINAs selected heating and building technologies (based *on* medium level of innovation)

Figure 14 and Figure 15 how the breakdown of employment by domestic/export market and across different cost categories i.e. construction, operation & maintenance and decommissioning, respectively.

As is the case for GVA, employment in the sector is projected to be principally serving the domestic market. The domestic market could support between 116,000 and 275,000 jobs in 2035 (81-91% of the total, depending on the scenario), potentially shifting to between 126,000 and 139,000 (75-77% of the total, depending on the scenario) by 2050. The drivers of these trends are the same as those for GVA, a growing export market and a stable but large domestic market. The stable size of the domestic market being the result of steady growth in the heat pumps market which is offset by a frontloaded insulation market.

Supported jobs by cost category follow the expected trend with jobs supported by construction activity being relatively more important in 2040 (between 67% and 80% of employment) but jobs supported by operation and maintenance (O&M) activity becoming more important by 2050 (between 32% and 38% of the total). The variation between the scenarios is driven by the deployment patterns – the build-up in wall insulation in 2040 in the High Diversification scenario leads to a boost in CAPEX jobs in that period that is not seen in the other scenarios.

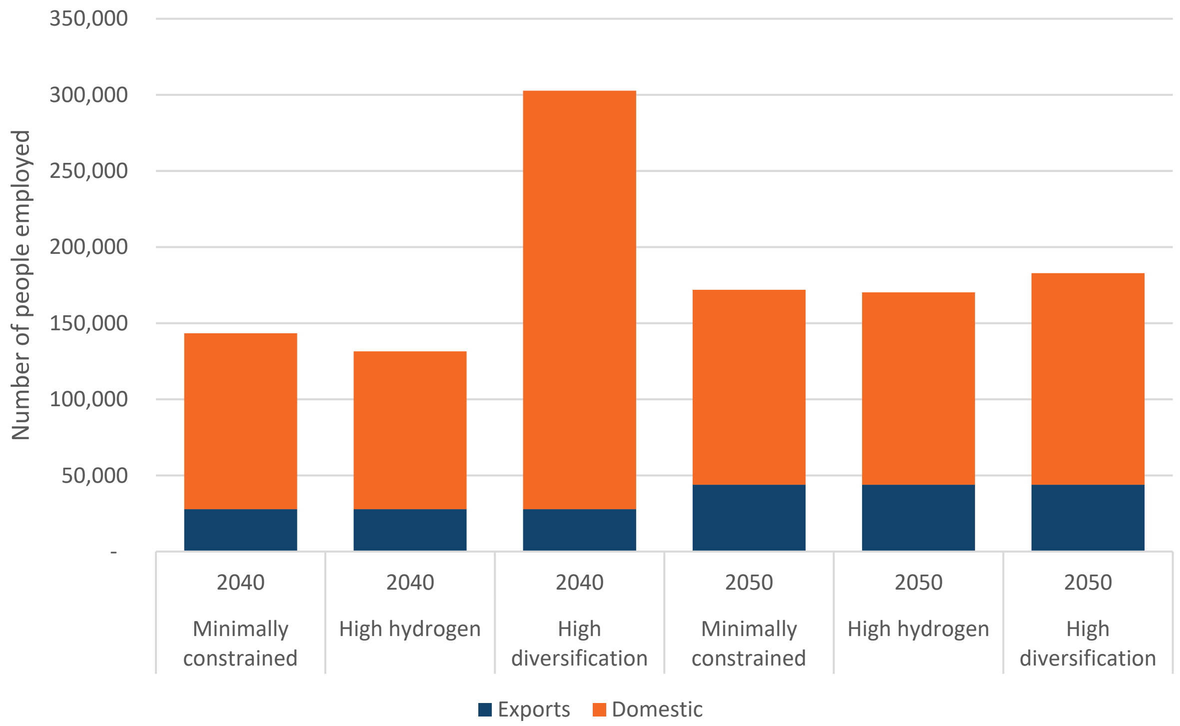

Figure 14: Total jobs supported (direct + indirect) by scenario by market for EINAs selected heating and building technologies (based *on* medium level of innovation)

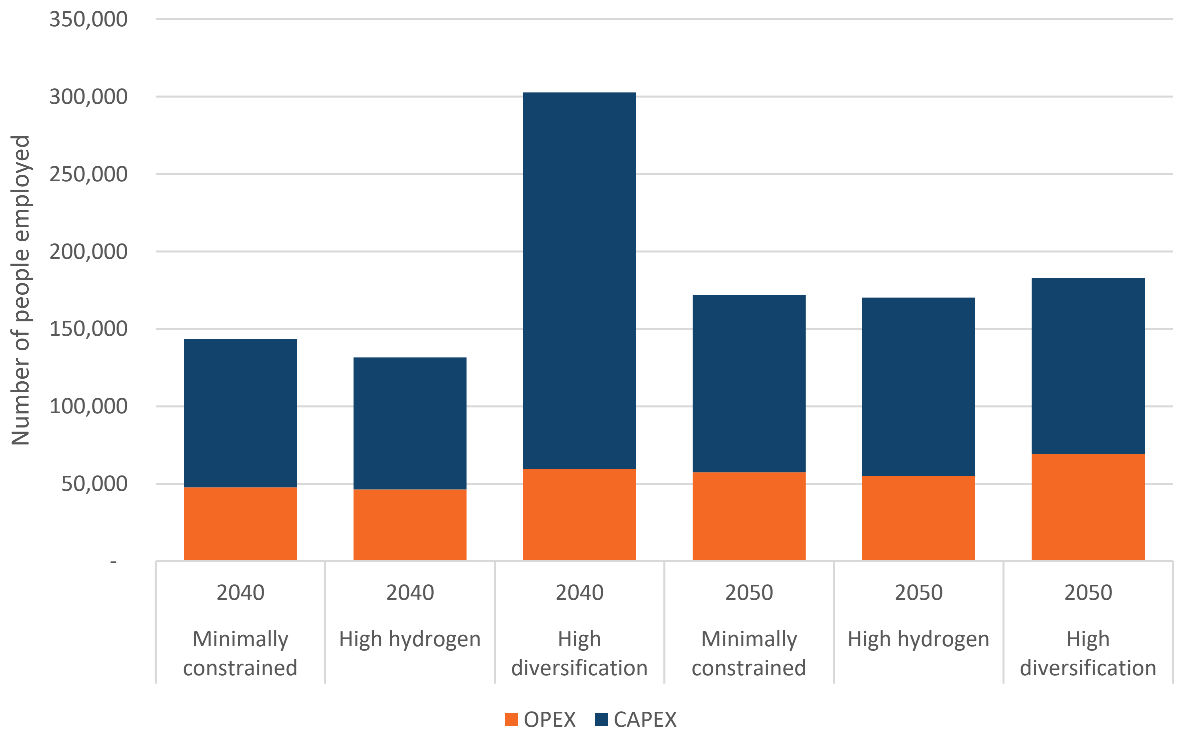

Figure 15: Total jobs supported (direct + indirect) by scenario by cost category for EINAs selected heating and building technologies (based on medium level of innovation)

Finally, Figure 16 shows that most of the direct jobs supported by the sector in 2050 are expected to be in skilled construction and building trades (31,000-32,000 direct jobs) followed by high skilled science, research, engineering and technology jobs (18,000-20,000 direct jobs). The large numbers of skilled construction and building trades reflects the skills needed for the installation and maintenance of heat pump and insulation technologies.

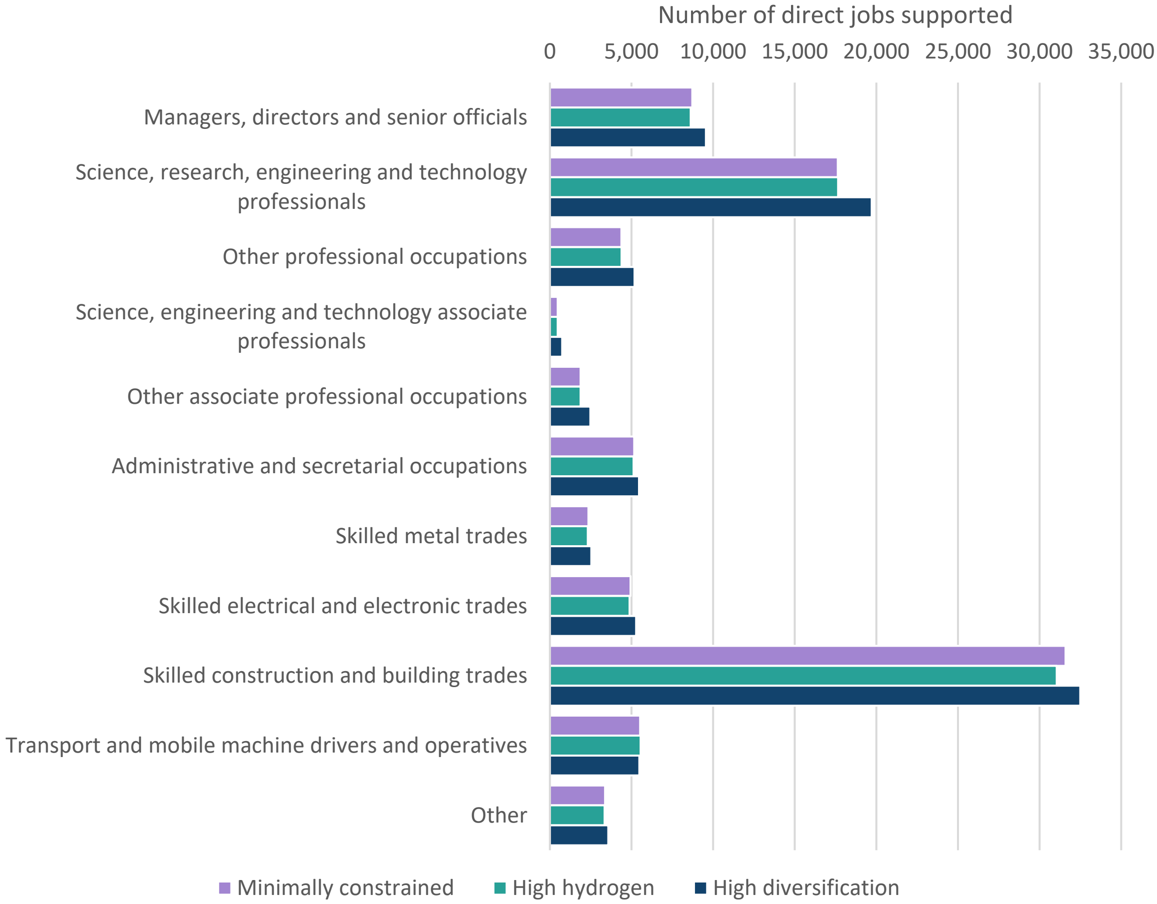

Figure 16: Direct jobs supported by scenario by occupation type in 2050 for EINAs selected heating and building technologies

Note: The figure reports outputs associated with a medium level of innovation. For the purposes of this analysis, the 412 4-digit SOC codes have been aggregated to 15 SOC groupings. See the EINAs Technical Methodology report for more details on this aggregation. In Figure 16 *the heading 'other' covers the following 5 SOC groupings: elementary occupations; process, plant and machine operatives; other skilled trade occupations; sales and customer service occupations; and caring, leisure and other service occupations.*

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