BRE Client Report

Energy Efficiency Capability Database Study

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1 Introduction

The Building Research Establishment Limited (BRE) understands that Scottish Enterprise's role is to help identify and exploit the best opportunities for economic growth, help build Scotland's globally competitive sectors, and supports ambitious Scottish companies to compete within the global marketplace. Furthermore, In light of growing local, national and international recognition of the significant commercial, economic and environmental benefits from increased energy efficiency, Scottish Enterprise is developing a strategic approach to maximising the associated economic benefit for Scotland.

Energy efficiency brings a wide range of benefits to households, businesses, society and the energy system as a whole. More efficient homes and buildings mean lower energy bills, improved health and comfort, and increased asset values for building owners. The UK Government Department for Business Energy and Industrial Strategy (BEIS) highlights that the UK energy efficiency products sector has a turnover of over £29 billion and employs over 100,000 people; and the UK is a net exporter of insulation and energy efficiency retrofit goods and services[1]. Improving energy efficiency is also one of the most cost-effective ways the UK has for meeting carbon budgets, and can lead to greater efficiencies and cost-savings across the wider energy system.

Critical to the Scottish Enterprise desire to maximise the economic potential for Scotland is the identification of the technologies of the new and existing sectors that are expected to emerge and grow as a result. It is within this context that BRE (with support from its partner Innovas Consulting Solutions Limited (Innovas)) was appointed by Scottish Enterprise to undertake an Energy Efficiency Company Study to support Scottish Enterprise when considering the development of a Scottish supply chain programme to support energy efficiency.

Research Need and Aim

Scottish Enterprise would like to identify the key technologies, company base and services of three key energy efficiency sub-sectors (as outlined below) in order to assess where Scotland has strong capabilities and a relative competitive advantage that can be promoted and developed, domestically and internationality. In addition the study aimed to identify potential gaps and weaknesses in capability and capacity in order to help Scottish Enterprise develop an informed view of existing and future capacity to assist in considering the merits of developing relative support for companies via specific initiatives and programmes, so that opportunities and economic benefits can be maximised.

The study was concerned with evaluating Scottish capability and emerging opportunities related primarily to technologies and/or technological solutions (both current and prospective commercial applications) associated with the following three energy efficiency sub-sectors:

1. Efficiencies in building fabric and related technologies.
2. Efficiencies in domestic heat, including space and water heating.
3. Efficiencies at a network or aggregated community scale (excluding district heating), which may include elements of Energy Systems technologies.

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[1] Call For Evidence – Building a Market for Energy Efficiency. BEIS. October 2017

The study aimed to have with a particular focus on both the Scottish Government's Scottish Energy Efficiency Programme (SEEP) objectives and also on potential international opportunities for Scottish organisations, over the next ten years (i.e. circa 2018 to 2028).

The study excluded analysis of non-technological solutions topics including 'service-led' aspects such as education/skills/training, installation quality, commercial services (e.g. legal, finance, etc.), etc. Equally, the study excluded examination of the district heating and cooling sector as well as the wider energy systems sectors as these topics have been the subject of similar studies in the past.

This report presents the research methodology employed to deliver the above, as well as key findings, conclusions and recommendations.

2 Methodology

The study aimed to analyse the following three key areas:

Analysis of Scottish Capability and Capacity: this included identifying the key sub-sectors and technologies within each of the three energy efficiency sub-sectors of interest to the study, and developing a database of Scottish capability in the sub-sectors based on existing knowledge and existing company information held by Scottish Enterprise. This stage was informed primarily by desk-based research augmented by in-house expertise

Market Analysis: This stage sought to provide quantified estimates of the size of the Scottish, UK and international markets for key sub-sector categories and technologies, as well as an analysis of key market drivers and potential future growth. The market analysis also enabled a 'mapping' of Scottish capability against the key market opportunities. This stage was informed by desk-based research, supplemented by company and stakeholder interviews.

Economic Benefit Analysis: This stage sought to provide a quantitative and qualitative assessment of the Energy Efficiency sector in Scotland and comment on its importance nationally and internationally, it's potential for future growth and key issues that could foster or constrain this growth. The assessment was informed in part by interviews with key businesses and surveys of other firms in the Energy Efficiency sector, and by quantitative modelling.

Methodology

The methodology employed to deliver the project consisted of project tasks as set out below.

- Task 1: Define the scope of each of energy efficiency sub-sector
- Task 2: Undertake a review of related research to establish previous studies or research relevant to the project.
- Task 3a: Market and geographical analysis to identify priority technologies and markets.
- Task 3b: Analyse sub-sectors and sub-categories and emerging opportunities offering greatest opportunities.
- Task 4: Business and stakeholder consultations
- Task 5: Mapping of Scottish capability against the sub-sectors and sub-categories and analysis of capability versus opportunities.
- Task 6: Modelling the impact of the Scottish energy efficiency sector.
- Conclusions and recommendation

The analysis is presented below.

3 Sub-Sector Definitions

As outlined above, the study was concerned with evaluating Scottish capability and emerging opportunities related primarily to technologies and/or technological solutions in three energy efficiency sub-sectors. The reader should be aware that the following sub-sector ‘scopes’ were agreed with the client as forming the basis for the study.

1. “Efficiencies in building fabric and related technologies”
    - This includes the full range of domestic and/or non-domestic building thermal elements (e.g. external walls, roofs, floors, partition walls, windows, doors, thermal bridging and air tightness, etc.) and the products, technologies or solutions that present opportunities for energy efficient improvements to the thermal elements.
2. “Efficiencies in domestic heat, including space and water heating”
    - This includes the full range of heat (space heating and/or water heating) generation, heat storage, heat emitter, heat recovery and heat control related products, technologies or solutions that present opportunities for energy efficient improvement in dwellings only i.e. non-domestic buildings are excluded.
3. “Efficiencies at a network or aggregated community scale (excluding district heating), which may include elements of Energy Systems technologies”
    - This includes emerging energy efficiency solutions (typically derived from aggregator based revenue streams) that involve the coordinated control of domestic energy systems in multiple dwellings to provide benefits for dwelling occupants and/or grid flexibility (e.g. demand side response, or similar).

Each sub-sector is explored in turn within sections 6-8 below.

4 Review of Policy, Research and International Energy Efficiency Trends

A review of policy background, related research and international energy efficiency trends was undertaken to provide background context on potential opportunities and markets to support the study. The review also ensured that the project work complimented and/or built upon existing research. A summary of key findings are presented below:

4.1 Policy Environment (Scotland and UK)

This study is to consider the implications and opportunities for technologies over the period of present of circa 2018-2028. It is therefore essential to understand the policy framework from the Scottish Government likely to be of influence over this timeframe, as well as other UK Government policies that may influence Scottish policy but which may also present opportunities to Scottish companies across the rest of the UK.

This study is set against the background of the UK's Climate Change Act 2008 which set a requirement for the UK to achieve 80% reduction in emissions by 2050. The UK and Scottish Government also recognise that progress must be made in progressive steps and this acknowledgement has led to an evolving Scottish and UK policy background which most notably includes the Scottish Government's Climate Change Plan[2] and Energy Strategy[3], and the UK Government's Clean Growth Strategy[4]. In addition to these broad overarching plans and strategies are a number of additional strategies, policies, programmes and/or proposed regulations that have increased focus and relevance to the energy efficiency sub-sectors. In addition, many of these policies and initiatives are likely to present significant opportunities for Scottish-based energy efficiency businesses of interest to the study. For example, these include the Scottish Government's Energy Efficient Scotland: Route map[5], Scotland's Energy Efficiency Programme (SEEP)[6], proposed Regulation of Energy Efficiency in Private Sector houses (REEPs)[7], as well as the UK Government proposals for Energy Company Obligations (ECO3)[8] over the period 2018-22.

Key aspects of the aforementioned policies are presented in detail in Appendix A and an overarching summary, in the context of this study, is presented below.

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[2] The Scottish Government: Climate Change Plan, Third Report on Proposals and Policies 2018-2032 (RPP3) (Feb 2018) https://www.gov.scot/Publications/2018/02/8867

[3] The Scottish Government: Scottish Energy Strategy - The Future of Energy in Scotland (Dec 2017) https://www.gov.scot/energystrategy

[4] https://www.gov.uk/government/publications/clean-growth-strategy

[5] The Scottish Government: Energy Efficient Scotland: Route Map (May 2018) https://www.gov.scot/Publications/2018/05/1462

[6] https://www.gov.scot/Topics/Business-Industry/Energy/Action/lowcarbon/LCITP/SEEP

[7] https://beta.gov.scot/policies/home-energy-and-fuel-poverty/energy-efficiency-in-private-rented-housing/

[8] https://www.gov.uk/government/consultations/energy-company-obligation-eco3-2018-to-2022

It is also worth highlighting that the Energy Saving Trust Scotland administer a ‘Home Energy Scotland Loan Scheme’ on behalf of Scottish Government which offers homeowners interest free loans (up to £15,000 max), and cashback (up to £3,750 max), for a range of energy efficiency measure and, renewable energy systems.

Policy Summary / key considerations

The Scottish Government have set new and ambitious targets for environmental performance as outlined in their Climate Change Plan (RPP3). In terms of building performance, the plan focuses on dramatic reductions in emissions from buildings, both residential and non-domestic, by 2032. This will be achieved through energy efficiency measures and the decarbonisation of heat, combined with the decarbonisation of electricity as far as possible, and a move towards the use of electricity to heat our homes.

The Climate Change Plan sets out a trajectory which requires:

- Reduction in domestic buildings’ heat demand by 15% through improvements to the building fabric by 2032.
- Reduction in non-domestic buildings’ heat demand by 20% through improvements to the building fabric by 2032.
- 11% of non-electrical heat demand to be from renewable sources by 2020.

Additional key statements within the Plan, that are appropriate to this study, include:

- The energy efficiency of Scotland’s residential and non-residential buildings will ensure that we keep our homes, schools and businesses warm while conserving energy.
- Over the period of the Plan, we expect to see an overall reduction in emissions of 33% from Scotland’s buildings.
- To achieve this, emissions from Scotland’s residential and non-domestic buildings will need to fall by 23% and 53% respectively.
- Where technically feasible by 2020, 60% of walls will be insulated and 70% of lofts will have at least 200mm of insulation in the residential sector.
- Improvements to the building fabric of Scotland’s buildings will result in a 15% reduction in residential and 20% in non-residential heat demand.
- Increases in the deployment of measures such as cavity wall, floor and loft insulation, secondary glazing, smart meters and programmable thermostats will provide consumers with opportunities for cost savings from reducing heat demand, help to alleviate fuel poverty and make businesses more competitive by releasing savings from fuel bills that can be invested in frontline services.

The Energy Efficient Scotland: Route Map sets out different ways of improving both domestic and non-domestic properties up to 2040 and by this date it is expected that all dwellings will achieve an EPC band C as a minimum. This offers potential for developers or suppliers of building fabric, space heating and/or aggregated energy efficiency technologies e.g.:

- The target for fuel poor households (which can be either owner occupied or rented) is to achieve EPC band C by 2030 and EPC band B by 2040.
- Social rented properties are to be improved significantly further and faster, with the target being that most homes will achieve EPC band B by 2032 and be as close to net zero carbon as soon as possible after this (this would be a high EPC band B or EPC band A).
- Private rented properties would require energy efficiency interventions at change of tenancy, but also a staged approach to ensure that all properties achieved EPC band E by 2022, EPC band D by 2025 and EPC band C by 2030.

Thus the approaches for other tenures are similar in some respects, but essentially for privately owned dwellings (households not in fuel poverty) the home owners will continue to be encouraged to improve their homes to and EPC band C by 2030, but after this it is suggested that it may be necessary to make this mandatory after 2030.

It is clear from the Route Map that it is expected that a larger proportion of households will need to have energy efficient interventions during the 2025 to 2035 period, the majority of these will require fabric and/or heating upgrades of some form. The focus on achieving EPC band C for most homes during this period would require commonly require a whole house energy efficiency intervention, although this does not necessarily equate to a single one-off upgrade, it could also be achieved by planning interventions in a (technically sensible) stepwise approach. The latter could for instance use a large cost effect initial energy efficiency intervention from which the savings in energy and therefore bills could be used to contribute to a later energy efficiency intervention that is less cost effective. Alternatively it may be possible to provide energy efficiency interventions at times when an intervention becomes possible such as when replacing kitchens or bathrooms for instance.

The recent Energy Companies Obligation (ECO3) sets out a similar pathway up to 2022, and confirms that UK Government funding of the same level as ECO would continue to at least 2028. ECO itself has also became a devolved issue since 2016 and thus the Scottish Government has the ability to adapt the ECO targets accordingly within the same funding horizon. Funding is also being provided directly from Social Housing providers and Local Authorities with substantial planned spending over the next three years.

The preceding text has focused rightly on the domestic refurbishment requirements as this will account for the greatest market share and also produce the greatest savings in energy use and bill reductions. That said the non-domestic sector will also be a major consumer of energy efficiency improvements for years to come. However the funding outlook for non-domestic is mixed. Scottish NHS for instance are currently not able to make long term plans for energy efficiency interventions because of the way they receive funding from the UK Government. Further/higher education on the other hand is planning for energy efficiency improvements over the next three years and beyond. Other business premises owners are also keen to pursue energy efficiency improvements, however here there seems to be a clear issue of an appropriate funding mechanism being available. This is an issue that the Scottish Government will be consulting upon shortly.

4.2 Relevant Studies

SEEP Technology Landscaping Studies

In 2017 ClimateXChange commissioned three landscaping studies[9] to identify and examine technologies that could support the delivery of SEEP. Separate studies were undertaken on the status of near-to-market (i) energy efficiency, (ii) heat generation and (iii) smart technologies, to feed in to the Research and Development work stream of SEEP. A summary of the findings is presented in sections 5, 6 and 7 in where each of the three energy efficiency sub-sectors are discussed in detail.

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[9] https://www.climatexchange.org.uk/research/projects/technologies-to-support-scotlands-energy-efficiency-programme/

UK Government – ‘Smart Power’, ‘Distributed Energy’ and ‘District Heating & Cooling’ Companies Database (delivered by Energy Systems Catapult)

The Department for International Trade (DIT), The Department for Business, Energy & Industrial Strategy (BEIS), and the Foreign Commonwealth Office (FCO) commissioned the Energy Systems Catapult[10] to develop a database so that UK companies operating in the ‘Smart Power’, ‘Distributed Energy’ and ‘District Heating & Cooling’ sectors do not miss out on opportunities to export home-grown products and services to overseas markets. Energy systems Catapult state that, in the EU, the Smart Power sector more than doubled between 2015 and 2017. The study highlights that global District Heating and Cooling market, by consumption volume, is expected to reach over £170 billion by 2024, growing at over 9% per year. The fast-paced growth of these sectors in international markets presents significant scope for UK companies. The database will be owned and maintained by the Energy Systems Catapult and will be used to promote UK expertise overseas.

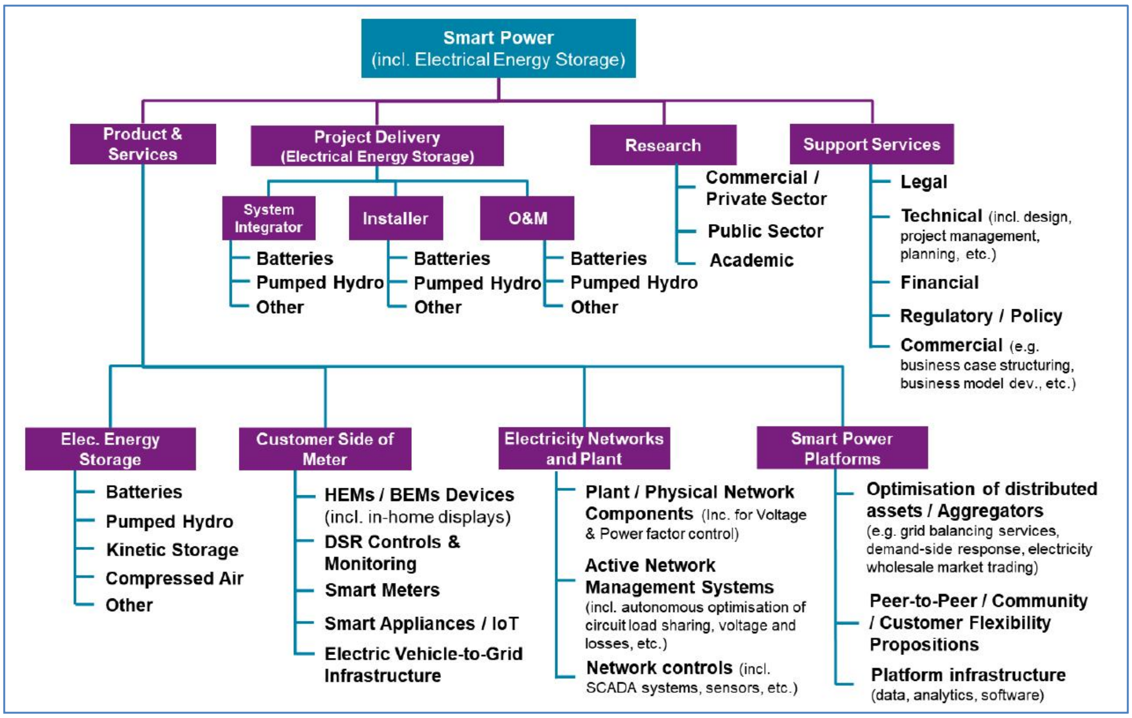

Figure 1: UK Government Companies Database ‘Smart Power’ sub-categories[11] (Source: Delta-EE)

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[10] https://es.catapult.org.uk/

[11] https://www.delta-ee.com/delta-ee-blog/slingshot-your-company-to-overseas-success-with-energy-systems-catapult-and-delta-ee.html

5 International Trends in Energy Efficiency

A detailed geographical market analysis of current international trends in building sector energy efficiency is provided in Appendix B. The analysis examines the International Energy Agency (IEA) Tracking Clean Energy Progress report[12] which provides a comprehensive and rigorous assessment of a full range of energy technologies and sectors that are critical in a global clean-energy transition. The report includes up-to-date information for where technologies are today and where they need to be according to the IEA's Sustainable Development Scenario (SDS) (a pathway to reach the Paris Agreement on tackling climate goal).

The IEA identifies decarbonising the power sector as a fundamental step to reducing emissions, complemented by efficiency improvements in buildings, in particular by addressing growing demand from cooling, heating and powered devices, and energy integration technologies will become increasingly important as shares of variable renewables rise.

The report highlights that the building sector is not on track to achieve global climate commitments but progress is being made with global initiatives, policies and technologies. The IEA report that highly efficient building envelopes can help enable more efficient use of renewable energy and higher efficiencies in equipment (e.g. it can increase the efficiency of heat pumps due to their being a lower temperature demand), as well as enable the use of additional energy sources (such as low temperature waste heat). The IEA also suggest that policy drivers such as building codes are creating market confidence in several parts of the world for new buildings that are energy-efficient.

A detailed summary is presented in Appendix B. Key points relating to each of the three sub-sectors of interest to the study are also summarised in the sections that follow.

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[12] IEA (2018).

6 Building Fabric and Related Technologies

This section considered the “efficiencies in building fabric and related technologies” sub-sector and presents key background research, market insights and emerging technology / opportunity analysis specific to this sub-sector.

As noted previously, the sub-sector includes “the full range of domestic and/or non-domestic building thermal elements (e.g. external walls, roofs, floors, partition walls, windows, doors, thermal bridging and air tightness, etc.) and the products, technologies or solutions that present opportunities for energy efficient improvements to the thermal elements.”

The building fabric energy efficiency sector is a mature one and whilst it has been established for many years various market drivers, manufacturing advances, product innovation and client demand has seen a number of new technologies and related services emerge and gain market significance.

Fabric Thermal Elements

When considering emerging opportunities in building fabric related technologies, it is useful to be aware of the individual building thermal elements, and their components / sub-groups. Each element and respective components will present a wide variation in relative energy loss as well as technical viability, ease and cost of having a thermally efficient upgrade applied. In addition to the individual thermal elements increasing focus needs to the applied to the junctions of each element type (e.g. where a wall meets a floor, a wall meets a roof, corners, areas around openings in walls, etc.) as there needs to be effective design and practical application of a suitably compatible combination of fabric intervention in those elements in order to reduce heat loss (e.g. via thermal bridging or similar).

A simplified analysis of building fabric thermal elements, and their related components, is presented below as background context and to the highlight the breadth of the sub-sector.

Thermal element / sub-elements		**Component opportunities for potential improvement**
Walls	External walls	cavity wall insulation
		internal wall insulation
		external wall insulation
		frame
	Party walls	masonry
		framed
Roofs		ceiling
		sarking
		flat
Floors	Ground	suspended timber
		suspended (other)
		solid concrete
	Upper	timber
		concrete
Windows/ doors	Glazing	triple glazing
		suspended film glazing
		secondary glazing
Associated fabric issues		Thermal bridging detailing
		Air tightness / draughtproofing

Table 1: Fabric thermal elements and generalised potential opportunities for energy efficiency improvement

The components listed above are likely to offer potential for energy improvement and thus carbon savings, however they all present different levels/magnitude of potential impact, varying capital cost and in-use savings all of which are often site specific. Generally speaking, greatest benefit can be achieved from undertaking energy conservation measures in fabric elements that are either poor performing to start with or components which generally experience comparatively high levels of heat loss relative to other components. It is also worth noting that there is generally an economic limit to installing insulation, beyond which point the addition of more insulation returns decreasing savings which are low in relation to the cost of the measure. For example, given current energy prices it is unusual to see the loft spaces of domestic properties insulated much beyond 300mm for this reason. Recent energy supplier obligation schemes (and their predecessors) have resulted in significant numbers of loft insulation and cavity wall insulation installation being carried out (including loft top-ups from levels of circa 50 – 100mm maximum) due to these measures offering greatest potential for carbon savings per pound of investment. As the number of ‘low hanging fruit’ opportunities such as these have been reducing other measures (such as external wall insulation, heating controls, etc.) that offer energy suppliers and/or consumer the next most cost effective measure have increased. Of course, the cost effectiveness of a measure is not only influenced by the capital cost of the refurbishment materials/equipment but also by a wide number of aspects including building use, occupancy numbers and patterns, fuel, site location, installation method, ease of installation and other technical considerations some of which are explored below.

Technical Considerations

Additional technical considerations relating to selected fabric upgrade opportunities, some of which are likely to present potential for innovation and/or growth, include:

External walls

- Cavity walls should not be filled in locations with high driven rain index unless the external leaf is suitable protected by cladding/render or are treated for prevention of rain penetration in some other way.
- Cavity walls with existing partial fill cavity wall insulation adds a level of complexity as introducing additional insulation can give rise to compatibility/warranty issues especially if different insulation materials are used.
- Cavity walls suitable for cavity wall insulation can be combined with either internal or external wall insulation techniques for further improved performance.
- External wall insulation can be applied to either solid walls or cavity walls. When applied to cavity walls, consideration should also be given to either filling (or potentially sealing) the cavity to prevent thermal bypass.
- Framed walls can be upgraded by replacing existing insulation or providing insulation for the first time. Internal wall insulation can be applied to existing wall finishes. External wall insulation can be used however any residual cavity in the framed wall should also be insulated to prevent thermal bypass.

Floor (ground)

- Insulation depths should typically be restricted to the depth of the joists in a timber suspended floor to ensure that cross ventilation of the subfloor void is maintained, unless the insulation system itself provides a suitable barrier to the presence of moisture in the floor void.
- Other suspended floor types and solid floors can be provided with over-floor insulation. However due to other related issues (door heights, stair risers, etc.) only a thin layer of insulation, and hence only modest thermal resistance improvements, tends to be possible.

Party walls

- Cavity masonry uninsulated party walls are subject to thermal bypass. This thermal bypass can be restricted by the suitable use of injected mineral wool, installed externally or from within the dwelling.
- Solid masonry party walls are commonly assumed to have no heat loss. In reality this is only correct if the adjacent properties are subject to similar occupancy patterns and similarly heated.
- Framed cavity party walls can be provided with injected mineral wool externally to restrict thermal bypass.

Thermal bridging detailing

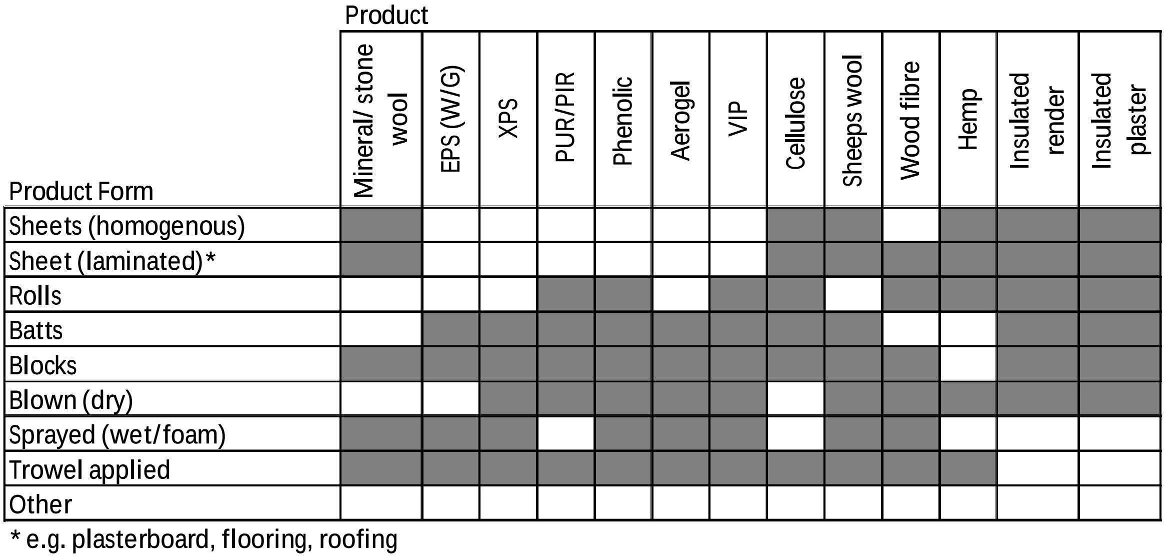
- Suitable treatment of thermal bridging is subject to the methods applied to upgrading adjacent thermal elements. Not treating thermal bridging heat loss can significantly reduce the overall effectiveness of improvements due to the large increase in thermal bridging heat loss (relative to through element heat loss) post refurbishment.

Airtightness/draughtproofing

- Providing insulation and associated vapour control layers will reduce unwanted air leakage and therefore make the dwelling more airtight. It is essential in terms of indoor air quality that this is considered in terms of how effective a dwelling is ventilated and that, where necessary, suitable ventilation equipment is installed at the same time as fabric improvements are undertaken.

Insulation products and forms

The table below presents current insulations products (traditional and emerging) and the forms that they can come in.



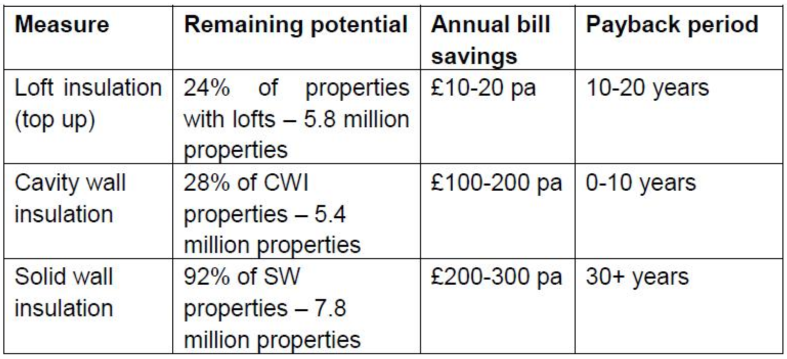
	Product												
Product Form	Mineral/ stone wool	EPS (W/G)	XPS	PUR/PIR	Phenolic	Aerogel	VIP	Cellulose	Sheeps wool	Wood fibre	Hemp	Insulated render	Insulated plaster
Sheets (homogenous)	▨							▨	▨		▨	▨	▨
Sheet (laminated)*	▨							▨	▨	▨	▨	▨	▨
Rolls				▨	▨		▨	▨		▨	▨	▨	▨
Batts		▨	▨	▨	▨	▨	▨	▨	▨			▨	▨
Blocks	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨
Blown (dry)			▨	▨	▨	▨	▨		▨	▨	▨	▨	▨
Sprayed (wet/foam)	▨	▨	▨		▨	▨	▨		▨	▨			
Trowel applied	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Other													

* e.g. plasterboard, flooring, roofing

Figure 2: Insulation products and their form (Source: BRE)

Remaining potential for selected traditional refurbishment techniques

A number of key emerging opportunities in this sub-sector are explored in section 6.3 however it is important to highlight that significant opportunities for reducing carbon emissions still exist in the UK that could be realised from the increased roll-out of energy refurbishment techniques as have been applied in recent and ongoing energy company obligation schemes. For example, the following table provides UK wide improvement potential for some common thermal insulation upgrades.



Measure	Remaining potential	Annual bill savings	Payback period
Loft insulation (top up)	24% of properties with lofts – 5.8 million properties	£10-20 pa	10-20 years
Cavity wall insulation	28% of CWI properties – 5.4 million properties	£100-200 pa	0-10 years
Solid wall insulation	92% of SW properties – 7.8 million properties	£200-300 pa	30+ years

Figure 3: Remaining potential for various insulation refurbishment measures in the UK (Source: BEIS[13])

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[13] BEIS call for evidence – Building a Market for Energy Efficiency. BEIS. October 2017.

It is worth noting however that a relatively high proportion of the remaining opportunities are likely to be in the owner occupier market which historically has been harder to engage. Some of the unfilled cavity walls may also include properties in locations of high driven rain index or possibly narrow/partially filled cavities. This is likely to offer potential for growth in the mid to long term for emerging products or techniques that reduce the effects of rain driven rain. Also, whilst the payback period reported above for solid wall insulation currently seem excessive, this more reflects the current cost of the works being high given that it is not yet a fully matured market. Solid wall insulation system improvements, and higher take up / volume of works, will most likely lead to cost reductions and reduced payback periods over time.

Similarly, the figure below helps re-inforce the opportunity that exists in domestic refurbishment. The figure below compares the average thermal transmittance (U-value) of selected elements in selected European/Scandinavian countries, however please note that the average U-values presented includes new build as well as existing elements.

Rank	Country	Walls	Country	Roof	Country	Floor	Country	Windows
1	Sweden	0.3	Sweden	0.2	Sweden	0.2	Finland	1.9
2	Finland	0.4	Denmark	0.3	Denmark	0.4	Austria	2.3
3	Denmark	0.5	Finland	0.3	Finland	0.4	Denmark	2.4
4	Czech Republic	0.8	Czech Republic	0.6	Germany	0.8	Sweden	2.5
5	Austria	0.9	Austria	0.6	Czech Republic	0.9	Germany	2.7
6	Germany	0.9	Ireland	0.7	Belgium	0.9	Czech Republic	2.7
7	UK	1.0	Germany	0.7	France	1.0	France	3.1
8	Netherlands	1.1	UK	1.1	Ireland	1.0	Netherlands	3.2
9	France	1.2	Netherlands	1.2	Austria	1.0	Belgium	3.8
10	Ireland	1.2	France	1.3	UK	1.2	Ireland	3.8
11	Belgium	1.5	Belgium	1.6	Netherlands	1.3	UK	3.9

Figure 4: Average U-values of walls, floors and windows in homes (Source: Smart Electric Heat: Kick-starting a Revolution in Heat. VCharge. October 2017. Original source noted as UKACE 2015.)

(BRE note on the figure above: The UK (and other countries) U-value for floors appear to be high as even an uninsulated solid floor in a detached dwelling will be no higher than 0.8 W/m^{2}K)

6.1 Key background research

ClimateXChange SEEP Technology Landscaping Studies (2017): Report 1 - Energy efficiency retrofit technologies

Key findings included:

- A total of 55 energy efficient technologies were identified of which, 44 (80%) are deemed suitable to domestic applications, 45 (82%) applicable to community buildings, 49 (89%) to public buildings, 46 (85%) applicable to commercial buildings but just 21 (38%) deemed applicable to industrial building types.
- The report highlighted that draught proofing and insulation remain the most effective energy efficiency measures.
- Rather than any new game changing energy efficiency technologies, the study highlights a landscape where incremental enhancements are being made. For example, it cites innovation being seen in:
    - Material enhancement – for example, in moisture management and resistance to fire and decay.
    - Novel systems – based upon off-site manufacturing, innovative system build-ups and taking a systems approach to improve airtightness and reduce thermal bridging.
    - Innovative surveying and installation - such as use of on-site laser scanning and site based robotics; allowing manufacturers, suppliers and contractors to work to high tolerances in the way they manufacture and install components.
    - Performance risk management – being largely addressed though the sheer range and diversity of products available to suit particular site requirements and building types.
- The study recommended that the SEEP programme also focuses effort in ensuring that any energy efficiency retrofit technologies are properly specified, designed, implemented and then verified through testing and evaluation.

IEA Tracking Clean Energy Progress Report

The summary below relates to building fabric considerations.

International Trends in Building Sector Energy Efficiency

General Trends

Global investment in energy efficiency increased by 9% to $231bn in 2016, maintaining the upward trend of recent years. The rate of growth was strongest in China at 24%, though Europe is still responsible for the largest share of global investment (30% of the total). Among end-use sectors, buildings still dominate energy efficiency investment, accounting for 58% of the world total in 2016, with most investment in that sector going to building envelopes, appliances and lighting.

However, the building sector is not on track to achieve global climate commitments but progress is being made with global initiatives, policies and technologies. Buildings, which were responsible for almost a third of final energy consumption in 2017, remain off track to meet the SDS target.

The energy and emissions savings potential remains largely untapped because of continued use of less efficient technologies, lack of effective policies and weak investments in sustainable buildings.

Highly efficient building envelopes can help enable more efficient use of renewable energy and higher efficiencies in equipment (e.g. it can increase the efficiency of heat pumps due to lower temperature demands), as well as enable the use of additional energy sources (such as low temperature waste heat).

Energy Efficiency in Buildings Policy Drivers

Building codes are creating market confidence in several parts of the world for new buildings that are energy-efficient. Beyond standards for efficient lighting and air conditioners, the potential to use standards to boost efficiency and save energy in whole buildings can be exploited through “green building” codes. Alongside national energy efficiency standards for individual building components, development and implementation of local whole-building green building codes that include energy efficiency requirements can help to drive up standards.

Progress on energy efficiency policies for buildings continues to increase, though the share of progress on building envelopes by country varies compared with progress on heating, ventilation and air conditioning (HVAC) equipment. In some countries, such as Denmark and Germany, building envelope policy has been the key driver for policy progress, while in other countries, such as Japan and Korea, HVAC equipment has been a key driver. A combination of both envelope and equipment policies is critical for the transition to sustainable buildings.

Energy Efficiency in Buildings Technology Drivers

Building Envelopes

Building envelope improvements are critical to achieve the transition to sustainable buildings, but most countries have still not made them an explicit policy priority. Nevertheless, progress is being made with global initiatives, policies and technologies. High-performance buildings construction, such as near-zero energy buildings (nZEBs), has picked up in a few countries, although it still represents a minor share of buildings construction. France is highlighted as a leader in the nZEB market, with a building code that requires all new construction to fall under its definition of an nZEB. In Austria, Belgium and Italy, more than 20% of residential new constructions in 2017 were nZEBs

On the renovation side, one notable development has been the expansion in 2017 of the Energiesprong programme, which is now present in four countries – France, Germany, the Netherlands and the United Kingdom. This innovative initiative seeks to achieve affordable zero-energy building retrofits.

Key Areas of Innovation

As countries seek to both shrink both their energy consumption and carbon footprint, improving the energy efficiency of buildings is being given high priority. Thousands of buildings are planned for renovation in the coming years, and more will be constructed or refurbished when stricter EU guidelines come into effect (e.g. in the EU in 2020).

In response, the energy-efficiency building sector is growing rapidly, especially in Europe. The European efficiency-related construction market is expected to be worth €140bn by 2020. Over the past decade the number of related intellectual property (i.e. patent) filings has tripled. The European Patent Office has identified four areas of building-related energy efficiency technologies in which innovation (measured by proxy by patent applications) is concentrated: heating and cooling; insulation; efficiency lighting; and self-powered buildings.

Heating and Cooling

Insulation and other fabric related materials

Energy-efficient heating can only keep a building warm if there is sufficient thermal insulation to keep the heat inside. Many commonly used, high-efficiency insulators were developed several decades ago and have seen gradual improvements and refinements since. These include:

- Insulating concrete formwork (ICFs), which use interlocking polystyrene concrete forms to create a seamless wall through which air cannot penetrate.
- Structural insulated panels (SIPs) are another frequently used insulation option, partly because they can be integrated into a number of materials, including particle and gypsum board, sheet metal, plastics and foams. They work by sandwiching insulation into interlocking sheets of building material to create uniform coverage.
- A new type of insulation, which employs a different thermal principle, has been creating a small sensation in the field since its emergence approximately 10 years ago. Unlike typical insulation that traps air in pockets (often between strands of fibrous material to resist the flow of heat), phase-change materials (PCMs) absorb or discharge heat as they change back and forth from a solid to liquid state. In a sense they "melt" and "freeze" at conditions close to room temperature and draw in or release heat in the process.

Future Growth in Energy Efficiency in Buildings

Energy Efficient Building Materials

The global ‘green building materials’ market size is expected to reach $364.6bn by 2022.[14] Growing demand for environmental-friendly and sustainable building materials is expected to propel the growth of the market.

Technological innovations have facilitated a rise in demand in green building materials, as products are becoming increasing affordable and readily available. As a result, the demand has increased dramatically over the past few years majorly due to rebounding construction market. Increasing demand for green building materials coupled particularly in emerging economies is expected to have a positive impact towards market growth. In addition, presence of large number of manufacturers is expected to increase the ease in sourcing the products. Oversupply of green building materials is expected to lower product price which is expected drive the market growth over the forecast period.

The market exhibits the presence of a large number of manufacturers engaged in the manufacturing of wide range of products including roofing, insulation, and frames. Easy accessibility to raw materials coupled with product demand is likely to increase industry rivalry which is expected to improve product quality.

6.2 Selected Market Insights

EU Energy Efficiency Directive – Energy Efficiency Targets

Energy efficiency is measured by primary energy consumption. Targets were set for EU member states according to the predictions made in 2005 (based on 1990 targets). Progress regarding a selection of countries is outlined below.

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[14] Grand View Research (2018).

The UK and France are currently not on track to meet their energy efficiency targets. EU member states in such a position may well be likely to further incentivize energy efficiency measures across all sectors.

By contrast, Poland & Spain are currently meeting their target. In Poland the target allowed for increasing emissions to allow for economic growth; Spain's economic slowdown has had a large contribution to reducing carbon emissions.

The UK is still short of its target but has achieved 86% of its target suggesting it is on course to achieve it with the current strategy.

France has only achieved 47% of its target suggesting that in order to meet its target, more ambitious policy measures will be required.

Member States	Target reduction (2005 – 2020)	2005	2010	2015	2020	Target gap	On track?
EU	13%	1,713	1,657	1,530	1,483	3.1%	N
Spain	12%	136	123	117	120	-2.6%	Y
France	15%	260	253	239	220	8.0%	N
Poland	-9%	88	96	90	96	-6.7%	Y
UK	20%	223	205	183	178	2.7%	N

Table 2: Primary energy consumption by country (Mtoe) (source: Eurostat[15])

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[15] http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_33&plugin=1

European Major Energy Retrofit Adoption Rates

Different research programmes have analysed the ‘rate of renovation’ for a number of European building stocks. The figure below provides an indication of ‘major renovations’ rates for European countries (as at 2016)[16]. Further analysis would be required in order to better understand the reasons for the low rate of retrofits however this may be due to issues including lack of public subsidies, private incentives and/or low household income.

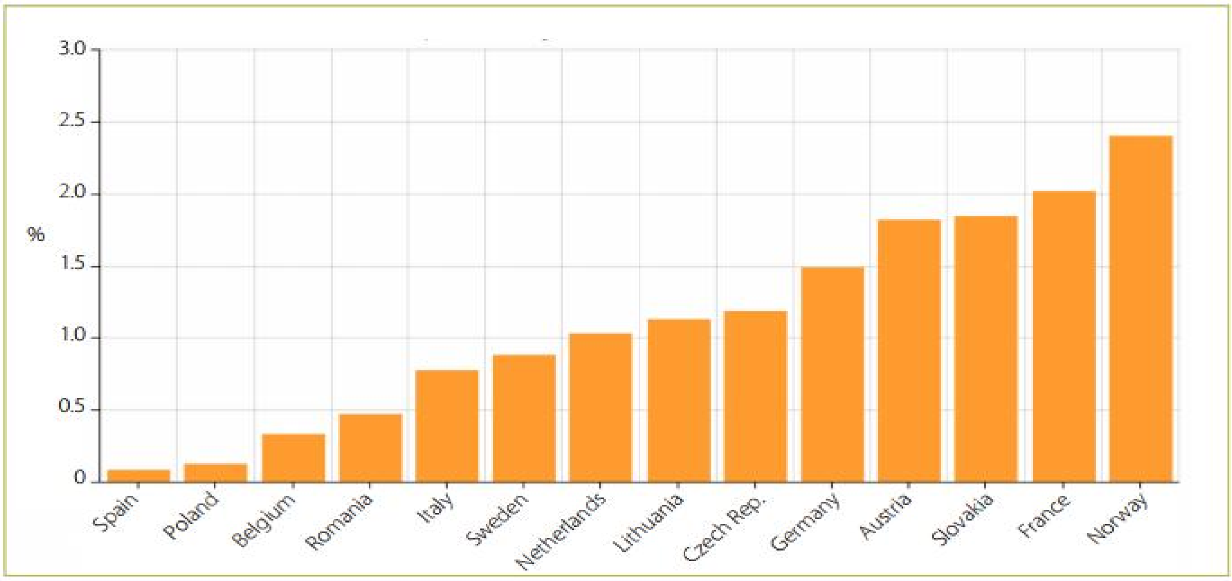

Figure 5: ‘Major renovations’ rates for selected European countries

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[16] Zebra 2020 - Nearly Zero-Energy Building Strategy 2020, Toleikyte, ZEBRA 2020

6.3 Key Emerging Opportunities

This section explores the fabric related technologies (and to some extent the applications) that are most likely to offer potential for significant growth in the next 10 years based on emerging market trends, innovation and ongoing research activities. The analysis is mainly focussed on the domestic refurbishment market as the main driver, however the technologies will, in the main, also apply to new build domestic as well as new build and refurbished non-domestic. It is worth noting that the list below is not definitive and that other building fabric technologies that can save energy, reduce carbon emissions or provide other useful benefits to consumers or building owners are also likely to offer potential over this timeframe.

1) Factory manufactured / off-site constructed fabric elements or systems

With surveying tools providing more accurate measurement of existing dwellings it makes it significantly easier to produce insulation products/panelling that can be manufactured off-site, to high levels of tolerance, for rapid installation on site as either an external or internal wall insulation product.

Reducing site fixing/altering of products not only safes time on site but more importantly can lead to much improved installation and increased performance of the installed products.

2) New, high-performing, insulation products

Products that include newer emerging insulation technologies such as aerogel blankets/boards and Vacuum Insulated Panels (VIPs) could provide significant improvements in reducing heat loss. These thin solutions by their very nature are less disruptive to install to any thermal element than current traditional insulation materials. This product type is suitable for installation on:

- above solid ground floors
- internally or externally on external walls,
- below/above flat roofs, upper exposed floors and balconies over heated spaces
- internally as sarking insulation
- treatment of locations of thermal bridging (jambs, cill, lintels etc.)

Correct installation techniques will need to be followed, especially for VIPs as these cannot be cut/damaged in any way as this would remove the essential vacuum characteristics of the product.

3) New / improved insulation retrofit techniques

For example, technologies and solutions that reduce impact on occupants, improve quality/consistency, reduce time and cost, etc.

Treatment of hard to treat situations have already led to new installation techniques being developed, or introduced. Hard to treat situations including;

- Cavity party walls (masonry or framed)
- Suspended floor sub-floor space either on the underside of the floor (spray foam) or filling the floor void (timber or concrete)
- Narrow or partially filled cavities or cavities in high wind driven rain index locations (masonry or framed)

With these new or improved techniques, it will be possible to return to previously upgraded properties to carry out further thermal improvements to elements previously disregarded for improvement.

4) Circular economy / embodied energy of building fabric components

There is a growing focus on green / sustainable building products and especially those that offer future re-use / recycle-ability.

Making more use use/re-use of existing materials in new and innovative ways will need to play a significant role in reducing future carbon emissions. The concept of re-use is not new, but near-term future developments/strategy will be able to focus on all levels of re-use and/or recyclability, including

- Single re-use of a material/product, taken from one property for use in another
- Single re-cycling of a material to transform into another product
- Re-use of a panel/system from one property to another
- Re-cycling of a panel or system by disassembly and re-use or recycling individually
- Re-use of an entire element from one property to another
- Re-cycling of an entire by disassembly and re-use or recycling individually
- Re-use of an entire building from one property to form another
- Re-cycling of an entire building by disassembly and re-use or recycling individually

It is clear that to achieve such a level of re-usability or recyclability will require a complete about face on how to design products and construction techniques. Although this would currently be more applicable to new build, the new building of today will become the buildings in need of refurbishment in the future and therefore there is a need to consider this in the near-term.

7 Domestic Heat

This section considers the “efficiencies in domestic heat (including space and water heating)” sub-sector and presents key background research, market insights and emerging technology / opportunity analysis specific to this sub-sector.

The sub-sector includes “the full range of heat (space heating and/or water heating) generation, heat storage, heat emitter, heat recovery and heat control related products, technologies or solutions that present opportunities for energy efficient improvement in dwellings only” i.e. non-domestic buildings are excluded.

Similarly to the building fabric sector, the domestic heating sector is also mature having been established for many years however various market drivers, emerging technologies and changing customer acceptance presents growing opportunities including some opportunity for new and/or emerging technologies.

Heat is at the core of Scotland’s energy system with the consumption of heat accounting for 51% of the energy consumed by Scotland’s homes and businesses (source: Scottish Government Energy Strategy[17]). This makes heat the biggest element of Scotland’s energy use and the largest source of its emissions. The Scottish heating market is dominated by gas boilers with approximately 79% of homes in Scotland in 2016 using natural gas as their primary fuel.

Domestic heat sub-categories

When considering emerging opportunities in domestic heat related technologies, it is useful to be aware of the full range of possible technologies and fuels serving the marketplace. Domestic heat generating technologies can generally be differentiated by whether a technology is principally a ‘space heating’ or a ‘water heating’ device, and then categorised by the ‘type’ of device or heat generating technology. Technologies can then be further sub-categorised by the primary fuel which is responsible for generating the heat / thermal energy. Other main heat related categories include energy (heat) storage, heat distribution, heat emitters, heat recovery and space heating controls and related products. A simplified analysis is presented below as background context and to the highlight the breadth of the sub-sector.

Application	Technology category	Sub-category
Space heat (or heating and hot water) generation technology	boilers	gas-fired
		oil-fired
		electric
		biomass-fired
		biogas-fired
		hydrogen-fired
	heat pumps	traditional heat pumps
		high temperature heat pump
		hybrid heat pumps

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[17] Scottish Energy Strategy, Scottish Government, December 2017

		gas driven heat pump
	cogeneration (CHP / mCHP)	gas / oil -fired
		biomass-fired
		biogas-fired
		hydrogen
		fuel cell (hydrocarbon)
		fuel cell (hydrogen)
	solar	solar thermal (space heating)

Table 3: high level categorisation of space heating technologies and sub-categories

Application	**Technology category**
Water heating	hot water cylinders (any type and fuel) and related components
	point of use water heaters (any fuel)
	hydrocarbon fired standalone heaters
	'renewable' derived water heater
	solar thermal (domestic hot water heating)
	PV thermal
Heat storage (including thermal stores)	electric storage heater / emitter (with storage)
	other electric / battery storage
	thermal stores
	phase change material
	fabric integrated storage
Heat emitters (non-storage)	radiators, convectors, radiant panels, etc. (wet)
	radiators, convectors, radiant panels, etc. (direct electric, non-storage)
	underfloor heating
	warm air
Heat recovery	ventilation heat recovery
	flue gas heat recovery
	waste water heat recovery
Heat distribution / circulation	pipework insulation
	circulating pumps and controls
	heat exchangers
	low temperature distribution technologies
	Hot water secondary return technologies / innovative control
Heat controls / metering / monitoring / user platforms	home energy monitoring products
	heat metering
	heating controls (traditional) (e.g. thermostat, TRVs, programmers, valves)
	heating controls (smart) (e.g. smart thermostats, home energy management systems)
	electricity to heat diverters

Table 4: High level categorisation of other (non space heating) domestic heat technologies and sub-categories

7.1 Key background research

SEEP Technology Landscaping Studies (2017): Report 2 – Heat generating technologies

Key findings included:

- That heat is at the core of Scotland's energy system with the consumption of heat accounting for 53% of the energy consumed by Scotland's homes and businesses (source: Scottish Government Draft Energy Strategy[18]). This makes heat the biggest element of Scotland's energy use and the largest source of its emissions. With the domestic sector space heating and water heating respectively accounting for 74% and 14% of total household energy use.
- The Scottish (and UK) heating market is dominated by gas boilers (~80% in Scotland).
- 21 distinct groups of heat generating technologies were identified, including the following which could supply domestic space heating and/or hot water:
    - high temperature heat pump, gas driven heat pump, hybrid heat pumps, solar-assisted heat pump, PV-thermal (PV-T) (hybrid solar photovoltaics), solar collector assisted, positive input ventilation, hydrocarbon fuel cell (cogeneration), hydrogen fuel cells (cogeneration), hydrogen burners / boilers, infrared heaters, electric storage heaters (high heat retention), waste water heat recovery and passive flue gas heat recovery.
- Some technologies are considered "add-on" or complimentary technologies i.e. they are unlikely to be able to meet the total space heating or domestic hot water energy demand of a property but rather they offer potential to usefully contribute to meeting part of this demand.
- High temperature, hybrid and gas driven heat pumps all have potential to increase the uptake of low carbon heating solutions in the UK in the short to medium term. However, a number of barriers exist to large scale uptake of heat pumps, including perception and lack of familiarity.
- The promotion of district heating also has a significant role to play – albeit focused more on 3rd and 4th generation systems than the large scale high temperature systems typical in other parts of Europe in the 1950s and 60s – due to the lower heating requirements of modern and retrofitted buildings.
- In the longer term the development of low carbon heating fuel markets may well present significant opportunity e.g. biogas (and also possibly hydrogen, although the widespread use of hydrogen as a heating fuel is likely to be some time away and it is also likely to have to compete with growing applications in energy storage and transport).

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[18] Draft Scottish Energy Strategy, Scottish Government, January 2017

IEA Tracking Clean Energy Progress Report

The summary below relates to domestic heat considerations.

International Trends in Heating

General Trends

In order to achieve the SDS targets by 2040 (against a base year of 2017, the IEA identifies decarbonising the power sector as a fundamental step to reducing emissions, complemented by efficiency improvements in buildings, in particular by addressing growing demand from cooling, heating and powered devices. However, to date, policies have focused primarily on the building envelope, rather than heating and cooling equipment.

Heating Policy Drivers

The residential sector utilises heating systems for space and water, and other utility purposes. Growing repair and renovation activities undertaken in North America and Europe coupled with increasing construction spending in the Asia Pacific and Middle Eastern region is projected to propel the demand for heating solutions over the coming years.

Europe is projected to experience high demand for energy-efficient and certified products. Favourable government policies related to reducing energy consumption are expected to boost the preference for technologically upgraded products and solutions. Demand from the Asia-Pacific region is projected to grow at the fastest rate in the medium term. Rapid industrialization and increasing R&D efforts to develop energy-efficient solutions is anticipated to lead to an acceleration in growth in demand over the coming years.

Heating Technology Drivers

Meters and controls are connecting buildings with big data. Including how energy use data can be used to make policy and building operation decisions that increase efficiency. This approach is enabled by increasing digitalization and the ability to capture and analyse large data sets.

Regarding increasing the efficiency of water heaters, more energy can be saved by switching between types of water heater than by increasing the efficiency of each equipment type; heat pumps enable energy savings of 60% to 85% compared with typical instantaneous and storage heaters.

Heat pumps are increasingly being recognised as a solution for many building energy needs. In the past, less sophisticated heat pumps did not efficiently operate in cold climates, however cold climate heat pumps are being introduced to the market that can operate much more efficiently and these could shift significant portions of global heating energy use away from less efficient electric and fuel heating systems in mixed and cold climates.

Heat pumps are an increasingly cost-effective way to meet both energy efficiency targets and countries' emissions reductions targets.

In recent years, condensing gas boilers, with efficiencies often higher than 90%, have gradually displaced coal, oil and conventional gas boilers, whose efficiencies are frequently less than 80%. But progress is not fast enough to meet SDS ambitions, which call for the use of high-efficiency fossil fuel equipment at the very least (e.g. condensing boiler technologies) and require a drastic shift towards clean energy technologies such as heat pumps and solar thermal heating.

Solar thermal heat capacity has increased by 250% over the last decade, and heat pump sales are increasing in many markets.

In Europe, heat pump sales increased by 20% in just two years, mainly driven by growth in air-source heat pumps. Yet despite this progress in Europe and elsewhere, significantly greater attention is needed to increase sales of high-performance heat pumps and solar thermal heating in buildings.

In Japan, the number of ENE-FARM hydrogen fuel cell units deployed annually remained steady, with a cumulative installation of 236,000 units at the end of March 2018. Most of these units are installed in single family homes and continue to benefit from subsidy support, which will remain until 2020.

Sales of heat pumps and solar thermal technologies for heating in buildings are growing, but this is dwarfed by sales of fossil-fuel based heating equipment. To date, only three countries explicitly mentioned heat pumps for water heating in residential or commercial buildings in their Nationally Determined Contributions submitted as part of the Paris Agreement.

To meet the SDS goals, the share of heat pumps and solar thermal heating needs to triple to more than one-third of new heating equipment sales by 2030. Alongside building envelope improvements, deployment of these low-carbon, high-efficiency heating technologies will help increase heating intensity improvements to around 3.3% annually in the coming decade. Improvement will be much faster in heating-intensive countries in Europe and Eurasia.

Key Areas of Innovation

About half of a building's total energy is devoted to heating, ventilation and air-conditioning (HVAC). So it is hardly surprising that the field has become a focal point for innovation. One of many promising HVAC patent areas is air purification, which incorporates technologies such as ultraviolet light and photo-reactive chemicals similar to those that occur in the Earth's atmosphere. Such systems enable buildings to reuse large amounts of their internal air and help lower heating costs.

Another up-and-coming field is passive solar and radiant heating, where warm, sunlit air is diverted to heat a building or, during the summer months, used to draw in colder air for ventilation. Such passive solar designs are used in many high-efficiency buildings.

Future Growth

The global space heating equipment market was worth $28.85bn in 2015 and is expected to witness considerable growth owing to the growing preference for energy efficient solutions.[19] Rapid industrialization coupled with increasing repair and renovation activities in the residential sector is projected to drive the demand for heating systems over the coming years.

One of the major trends influencing the heating equipment market is demand for products that are certified as energy efficient.

The heating equipment industry is highly competitive, and companies are at the risk of losing business owing to several factors including price, technology, product performance, geographic presence, and customer service.

Heat pumps accounted for 42.7% of the global revenue in 2015. Heat pumps are projected to grow rapidly.

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[19] Grand View Research (2016)

7.2 Selected Market Insight

Most low carbon pathways suggest that heat pumps will play a large role in decarbonising the UK economy. In 2015, the Committee on Climate Change (CCC) has suggested that the overall cost-effective uptake of heat pumps in UK homes could reach 2.3 million by 2030[20].

National Grid's 'Future Energy Scenarios 2018'[21]

More recently, National Grid's 'Future Energy Scenarios 2018' suggests that in order for the UK to be on a pathway to 2050 compliance in terms of carbon reductions, that the number of heat pump installation will need to rise from the 2017 level of circa 0.04m to at least 2.72m by 2030 (the modelled scenario also includes a number of other ambitious decarbonisation targets across other energy sectors including energy generation, renewables, transport, etc.). It is also worth highlighting that even the, non 2050 compliant, 'Steady Progression' pathway would require a 12-fold increase to 0.48m units by 2030.

Domestic Heat Pump Trends

The current UK market for heat pumps is small; around 18,700 units per year, of which around 17,700 are estimated to be domestic[22].

The domestic scale air-air heat pump market is well established in France and Spain (see figure below). In both they typically provide cooling as well as heating and are considered as a reasonable solution for rural properties.

Both the UK & Poland have negligible numbers of heat pumps partly due to the lower cooling requirement but also due to lower heating efficiencies and cheaper alternatives (i.e. gas in the UK & coal in Poland).

Air-Water heat pumps have some increased market share in France.

Regarding subsidies; France provides subsidies for air to water (as does the UK) but there is better success of uptake due to the lack of gas networks in many French rural areas. Spain is less successful due to lack of subsidies.

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[20] Sectoral scenarios for the Fifth Carbon Budget, Technical report, Committee on Climate Change, Nov 2015

[21] http://fes.nationalgrid.com

[22] Evidence Gathering – Low Carbon Heating Technologies - Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report, BEIS, November 2016

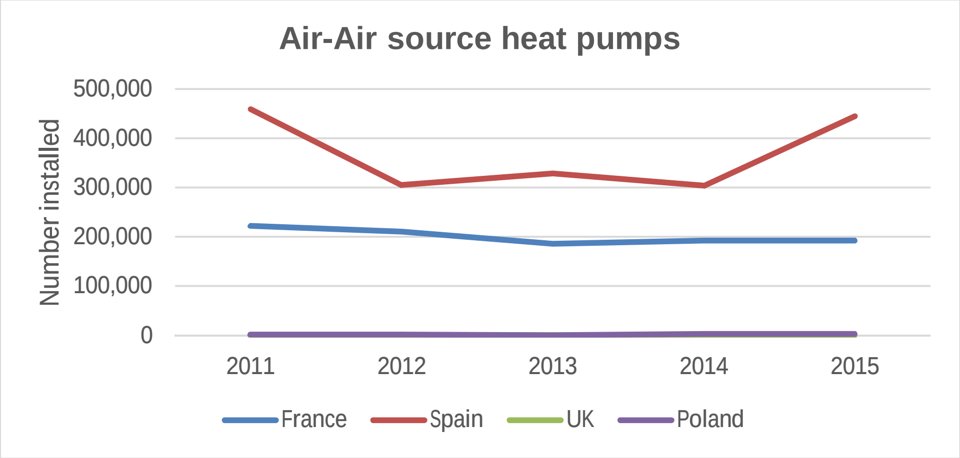

Figure 6: Air-air source heat pump installations in selected EU countries (source: Chiffres clés des énergies renouvelables, EurObserver & Ofgem)

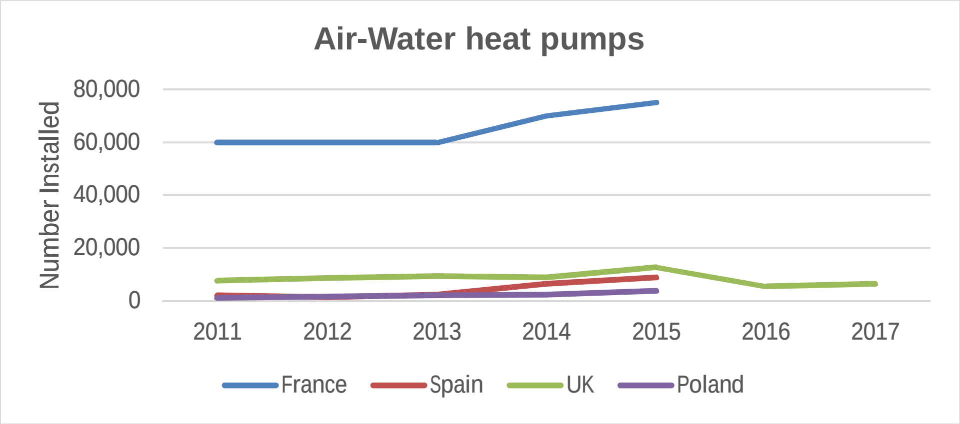

Figure 7: Air-water source heat pump installations in selected EU countries (source: Chiffres clés des énergies renouvelables, EurObserver & Ofgem)

7.3 Key Emerging Opportunities

This section explores the domestic heat related technologies (and to some extent the applications) that are most likely to offer potential for significant growth in the next 10 years based on emerging market trends, innovation and ongoing research activities. The analysis is focussed on the domestic market including new build and refurbishment. It is worth noting that the list below is not definitive and that other space heat related technologies that can save energy, reduce carbon emissions or provide other useful benefits to consumers or building owners are also likely to offer potential over this timeframe e.g. solar thermal derived heating including space heating, renewable heat technologies, heat recovery, etc.

1) Heat Pumps

Emerging heat pump technologies such as high temperature, hybrid and gas driven heat pumps are likely to offer growth significant potential in the UK (and Europe and beyond) in the short to medium term.

1A) High temperature heat pumps

- High temperature heat pumps are generally considered to be products capable of producing an output temperature of at least 65°C.
- High temperature heat pumps are particularly suited for off gas grid retrofit projects, and hybrids and gas driven products are suited to on gas grid properties. They may all be used with no or limited upgrades to existing heating systems. Each offers some advantages (but also some disadvantages) compared with standard electric heat pumps, but it is not yet clear that these advantages are sufficient to stimulate widespread uptake of the technologies.
- High temperature heat pumps may remain a niche market in the short term. Their target market tends to be large, old, or listed properties (i.e. with high heat loss), often off the gas grid and with high domestic hot water demand.

1B) Hybrid heat pumps

- A hybrid heat pump system is considered here as an electric air to water or ground to water heat pump combined with a fossil fuel fired boiler; a means of inputting the heat into an existing heat distribution system; and a dedicated control system to switch between the two sources. Both hybrid package heat pumps and hybrid ‘add-on’ heat pumps (for retrofitting to an existing boilers) are possible.
- Hybrid heat pump are widely expected to be a competitive low-carbon transition technology, delivering the carbon saving benefits of an electric heat pump with the performance of a gas boiler when required.
- Hybrid heat pumps can also offer ‘demand management’ opportunities.

1C) Gas heat pumps

- Gas heat pump technology can be split into sorption heat pumps and gas engine driven heat pumps. Sorption heat pumps can be split into two types – adsorption and absorption. Sorption units use a thermal compressor to heat the refrigerant, whereas gas engine driven heat pumps use a mechanical compressor (similar to electric heat pumps) but where the energy source is gas.
- Gas driven heat pumps may help to overcome consumer inertia (as consumers are familiar with gas fired heating and these heat pumps use gas as their main fuel), however they are still very new in the domestic market and present high initial capital cost.
- Being fuelled by gas means that large scale roll-out of gas driven heat pumps will present a negligible/low impact on the electrical network (/grid). This is in stark contract with other, electrically driven, heat pump technologies. As a result they could potentially offer increase potential for ‘whole of system’ efficiencies to be realised.

A high level comparison of high temperature, hybrid and gas driven heat pump technologies, extracted from BEIS’s “Evidence Gathering - Low Carbon Heating Technologies: Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report”[23] publication is provided in the figure below.

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[23] https://www.gov.uk/government/publications/evidence-gathering-high-temperature-heat-pumps-hybrid-heat-pumps-and-gas-driven-heat-pumps

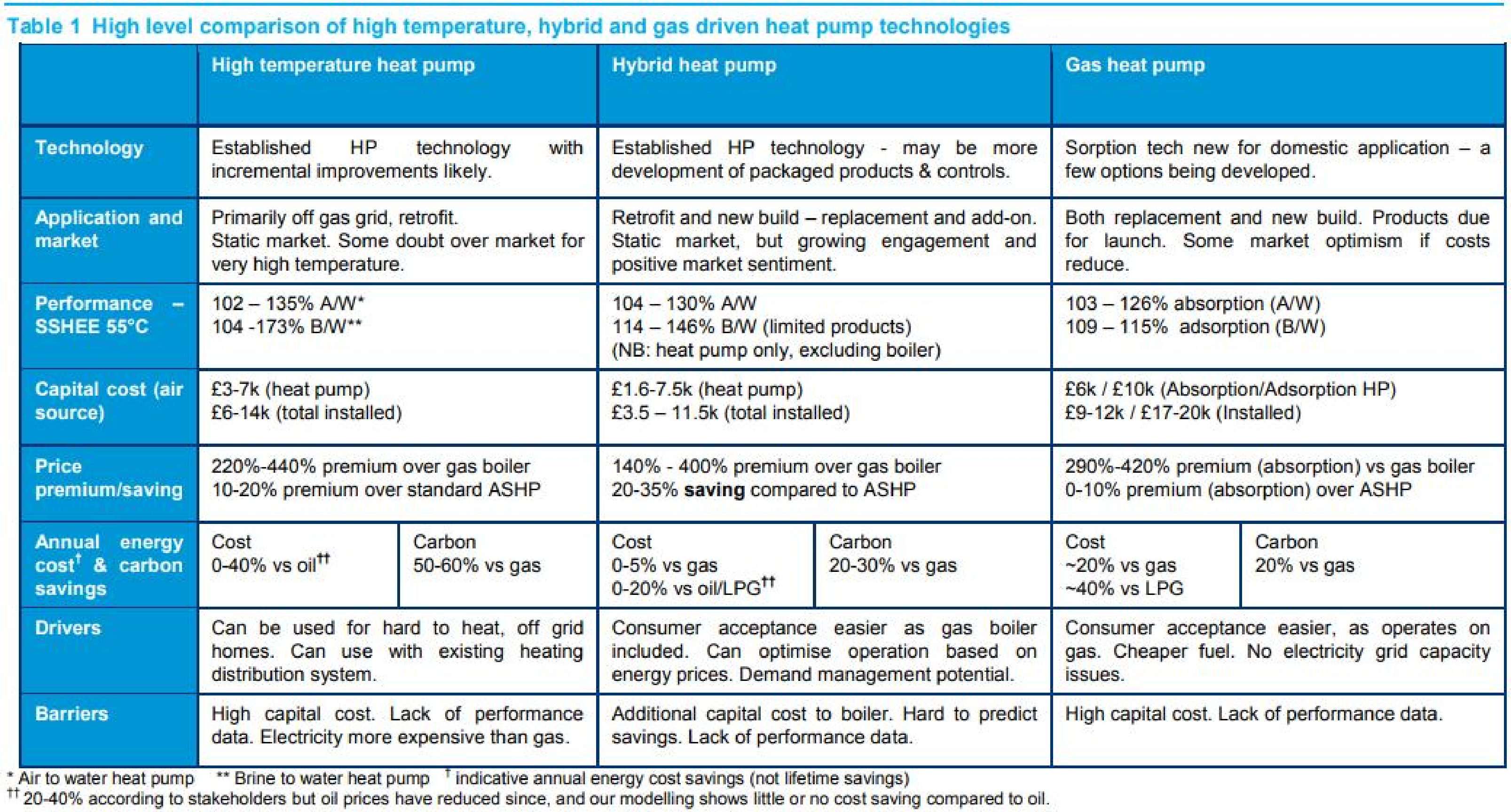

Table 1 High level comparison of high temperature, hybrid and gas driven heat pump technologies

	High temperature heat pump	Hybrid heat pump	Gas heat pump
Technology	Established HP technology with incremental improvements likely.	Established HP technology - may be more development of packaged products & controls.	Sorption tech new for domestic application – a few options being developed.
Application and market	Primarily off gas grid, retrofit. Static market. Some doubt over market for very high temperature.	Retrofit and new build – replacement and add-on. Static market, but growing engagement and positive market sentiment.	Both replacement and new build. Products due for launch. Some market optimism if costs reduce.
Performance – SSHEE 55°C	102 – 135% A/W* 104 -173% B/W**	104 – 130% A/W 114 – 146% B/W (limited products) (NB: heat pump only, excluding boiler)	103 – 126% absorption (A/W) 109 – 115% adsorption (B/W)
Capital cost (air source)	£3-7k (heat pump) £6-14k (total installed)	£1.6-7.5k (heat pump) £3.5 – 11.5k (total installed)	£6k / £10k (Absorption/Adsorption HP) £9-12k / £17-20k (Installed)
Price premium/saving	220%-440% premium over gas boiler 10-20% premium over standard ASHP	140% - 400% premium over gas boiler 20-35% **saving** compared to ASHP	290%-420% premium (absorption) vs gas boiler 0-10% premium (absorption) over ASHP
Annual energy cost[†] & carbon savings	Cost 0-40% vs oil[††] Carbon 50-60% vs gas	Cost 0-5% vs gas 0-20% vs oil/LPG[††] Carbon 20-30% vs gas	Cost ~20% vs gas ~40% vs LPG Carbon 20% vs gas
Drivers	Can be used for hard to heat, off grid homes. Can use with existing heating distribution system.	Consumer acceptance easier as gas boiler included. Can optimise operation based on energy prices. Demand management potential.	Consumer acceptance easier, as operates on gas. Cheaper fuel. No electricity grid capacity issues.
Barriers	High capital cost. Lack of performance data. Electricity more expensive than gas.	Additional capital cost to boiler. Hard to predict savings. Lack of performance data.	High capital cost. Lack of performance data.

* Air to water heat pump ** Brine to water heat pump [†] indicative annual energy cost savings (not lifetime savings)
[††] 20-40% according to stakeholders but oil prices have reduced since, and our modelling shows little or no cost saving compared to oil.

Figure 8: High level comparison of high temperature, hybrid and gas driven heat pumps (source: BEIS: 2016)

The BEIS analysis highlights that all of the above heat pump technologies can deliver cost and carbon savings compared with a standard electric heat pump, particularly where expensive and disruptive upgrades to the heat distribution system would otherwise be required. However only gas driven products are likely to deliver a significant operational cost saving versus a new gas boiler. In terms of overall impact, it should be noted that all of the above heat pump technologies can deliver a carbon saving compared with a gas boiler. This is important in relation to assessing the likely energy efficiency, climate impacts and potential fuel poverty impacts of moving to these technologies at a point in time where gas costs are low in relation to other fuels.

It is also likely that the domestic heat market will see increasing innovation in terms of new ‘heat delivery’ business models (e.g. suppliers offering the provision of ‘heat as a service’ to consumers, or similar) that includes growing use of hybrid electric / gas technologies (e.g. hybrid heat pump / gas boiler, or similar) and/or thermal storage. This is explored in more detail under aggregated solutions in the next section.

Barriers

Despite their impressive environmental credentials, it is important to note that there are a number of significant barriers that are likely to impact upon large scale uptake of heat pumps. These include, amongst others, issues regarding consumer perception of, and lack of familiarity with, heat pump technology. This means that there is a significant inertia that needs to be overcome much of which is caused by consumer’s expectations regarding system performance given the UK’s familiarity with gas boilers. Specific types of emerging heat pump technology can however help overcome these issues, e.g.:

- Heating system temperature expectations: High temperature, hybrid and gas driven products can help to mitigate some of these traditional barriers, as most can provide the high temperature space heating outputs that customers are used to, and can also supply domestic hot water. These systems could therefore help overcome the consumer inertia that currently ‘favours’ conventional gas boilers, however the provision of the higher temperature incurs a capital cost and carbon saving penalty versus traditional heat pumps. Furthermore, hybrid and gas driven products may help overcome other barriers associated with moving away from gas fired heating systems.
- Capital Cost: These technologies still suffer from high upfront cost, the need for additional space, and low customer awareness and associated lack of acceptance.
- Lack of performance data: These systems are new to the market and as a result there is a lack of trial information so the cost benefits and performance remain generally unproven.
- Consumer awareness and technology risks: similar to above, trials and on-site testing are needed to test these technologies, their practical applications as well as build consumer knowledge, acceptance and trust.

2) Other low carbon heat technologies

Other low carbon heat technologies (e.g. solar thermal, biomass, traditional heat pumps CHP technologies, etc.) are also likely to need to play an important role in decarbonising the Scottish domestic heat market over the next 10 years and beyond. This is especially true in the short to medium term (e.g. until such time as the above emerging heat pump technologies can mature, reduce in cost, etc.) and for rural / off-gas grid properties, as a significant barrier to wider roll-out remains the relatively low cost of gas boiler and gas fuels for areas on or near to the gas network. Hybrid heating systems could however play an increasing role for on-gas grid properties.

3) ‘Smart’ heating controls / heat storage / demand response technologies

Hybrid heating, energy storage (including storage heaters) and smart controls are also key facilitating technologies for ‘aggregated solutions’ as discussed in the next section.

8 Network or aggregated energy efficiency solutions

This section considers the “efficiencies at a network or aggregated community scale (excluding district heating), which may include elements of Energy Systems technologies” sub-sector and presents key background research, market insights and emerging technology / opportunity analysis specific to this sub-sector.

As noted previously, the sub-sector includes “emerging energy efficiency solutions (typically derived from aggregator based revenue streams related to demand side response, or similar) that involve the coordinated control of domestic energy systems in multiple dwellings to provide benefits for dwelling occupants and/or grid flexibility.”

Additional background information pertaining to ‘flexibility’ methods emerging as part of the UK and Global transition to smarter energy systems is presented below to serve as an introduction to the key emerging opportunities in this sector.

8.1 Introduction to Flexibility

Background

The UK’s energy system is changing and this presents a number of opportunities for innovative companies and solution providers. The 2008 Climate Change Act committed the UK to reducing emissions by at least 80% in 2050 from 1990 levels. Meeting this target would likely require heat related emissions of CO_2 from buildings to be near zero by 2050. Both targets pose an enormous economic and environmental challenge to energy providers. In the recent past, the expectation from the government and others had been that gas networks would be switched off within the next 20-30 years, to be replaced by electrified heat, however it is becoming clear that the electrification of heat brings with it many technical and economic challenges. In turn this offers potential for other technologies during the transition.

Enabling smart technology

One of the challenges is for the energy sector to transform towards a more flexible, increasingly decentralised power system, which enables smart technologies to improve whole system efficiency. It is important that the energy system is able to match increasing levels of intermittent supply (e.g. from renewables) on the system with levels of demand. For example, consumers can benefit from increased flexibility through actively choosing to adapt their energy usage through smart tariffs, smart appliances or by supplying excess electricity to the system to aid in network balancing and provide value to the wider energy system. This transition towards a smarter energy system is growing pace, however it is important to recognise smart meters as a key enabler to achieving the end goal of providing benefits for the customer and energy sector alike. Smart meters will allow for the aggregation of value from energy assets (storage, electric vehicles, distributed generation such as solar PV, etc.), as well as enabling the integration of smart appliances and a range of energy management systems. Once adopted, smart meters (i.e. second generation specification / SMETS2) should provide the central function of allowing the adoption of connected home technologies and enabling a host of innovative energy solutions that provide value to the networks and customers.

Flexibility of demand

As the energy system adapts to a range of small-scale distributed energy resources and as intermittent renewables play an increasing role, it is important that adjustments to supply and demand can be made at multiple points. Instead of a top down flow of information and power, smart systems will enable multiple interactions and reactions to keep the system in balance.

Ofgem define flexibility as “modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system”[24].

To date, the energy industry has typically provided flexibility on the ‘supply-side’. For example, to make sure supply always matches demand, electricity power stations have changed how much they produce. Network operators have also built enough infrastructure (transformers, cables, etc.) to make sure electricity can always be transported to consumers. However, our energy system is changing and continuing to rely on supply-side solutions alone would be expensive. As a result new ways of providing flexibility are emerging that offer potential for businesses and which can also help the UK deliver against our carbon commitments, while providing reliable and secure supply at minimum cost to consumers.

‘New’ flexibility methods include:

- Demand-Side Response (DSR):
  - Consumers (the ‘demand-side’) can sign up to special tariffs and schemes which reward them for changing how and when they use electricity (known as ‘demand-side response’. Smart meters and other technologies will make this easier than ever for domestic consumers. DSR is an important element of a flexible energy system.
- Energy storage
  - Batteries or other forms of storage (i.e. both electrical and thermal energy storage) can be used to store energy when it is plentiful, or when there is too much for network cables to carry. This energy can then be used at a time when it’s needed.
- Distributed generation
  - Local use of low carbon electricity we generate locally at home or at work, such as from a rooftop solar panel, to help reduce the costs of transporting it and save money on bills.

As noted above, Demand Side Response (DSR) is the term given to a range of options which encourage customers to increase or decrease the amount of energy they are using based on signals from the network. The majority of the existing UK DSR market is based on the displacement of demand at peak times, and is operated through a range of aggregators. These aggregators typically contract with multiple industrial and commercial customers to create a single larger asset, better aligning local energy use with the requirements and available supply of the system. As the sector evolves aggregators are becoming increasingly interested in new opportunities that provide demand side response capacity and this is giving rise to innovative new ways of supplying and/or controlling power, heat and transport demand within the built environment sector.

DSR has a significant role to play in supporting the transition to a more flexible and responsive energy system by offering an alternative to generation and facilitating a smoother demand curve. The December 2016 Capacity Market Auction saw DSR win over 1.4 GW of capacity agreements, and UK DSR capacity is set to grow further, as National Grid has set a target of meeting 30-50% of balancing services with DSR by 2020.

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[24] https://www.ofgem.gov.uk/electricity/retail-market/market-review-and-reform/smarter-markets-programme/electricity-system-flexibility

Aggregated energy efficiency sub-categories

This section presents a high level summary of relevant aggregated energy efficiency sub-categories. The sub-categorisation attempts to compliment the hierarchy developed for the UK Government – 'Smart Power', 'Distributed Energy' and 'District Heating & Cooling' Companies Database project (as discussed early) as highlighted in the figure below.

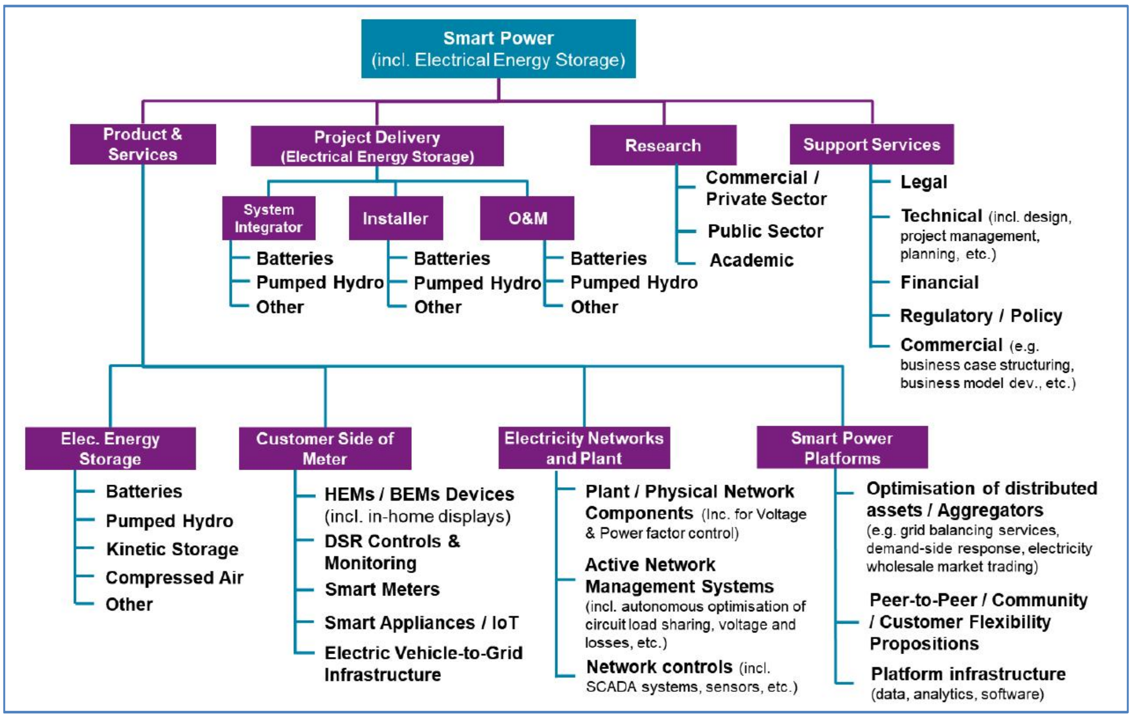

Figure 9: UK Government Companies Database 'Smart Power' sub-categories (Source: Delta-EE)

Considering the figure above, the sub-sector areas that are most relevant to this study are aspects of 'Customer Side of Meter', and 'Smart Power Platforms'. These are expanded below.

Category	**Sub-category**	**Comments**
Smart meters		e.g. hardware, software, data, connectivity.
Smart appliances		
Home energy management systems		e.g. including local sensors, controls, in-home displays, etc.
Demand Side Response	Monitoring and controls	e.g. sensing, integrated controls, actuation, communication.
	Heating and hot water systems	e.g. flexible heating, hybrid systems, hot water, thermal storage.
	Electrical energy systems	e.g. smart storage heaters, smart appliances, energy diverters.
	Energy Storage	e.g. electrical storage (batteries), thermal stores, phase change material.
	Electric vehicles to/from grid	

Distributed generation	Optimisation and control of on-site generation	

Table 5: High level 'Customer side of the meter' aggregated solution technologies

Category	**Sub-category**	**Comments**
Platform infrastructure		data, analytics, software.
Optimisation of distributed / aggregated assets		sensing, modelling, intelligent control.
Peer-to-peer trading		data, analytics, software.

Table 6: High level 'Smart power platforms' aggregated solutions technologies

8.3 Key background research

SEEP Technology Landscaping Studies (2017): Report 3 – Smart energy technologies

Key findings includes:

- That, broadly speaking, smart technologies are seen as enabling flexibility in parts of the energy system that have previously been inflexible – for example flexing demand to low carbon generation patterns (as opposed to flexing fossil fuelled generation to demand patterns), or facilitating active participation of customers in understanding and controlling energy consumption, or letting intelligent devices do this for them.
- The study is a bottom-up approach, starting with the technologies on the ground that can make a difference to energy efficiency, and assess their potential to grow and their impact on people and the environment. Other studies have taken a more top-down approach looking at the conditions favourable to seeding new smart technologies.
- Network companies are moving towards a Distribution System Operator (DSO) model where they will play a key role in facilitating local energy balancing markets. This represents a significant shift from the traditionally passive distribution networks acting as a conduit for centralised control actions from a nation-wide system operator. Central to the DSO is the increased visibility of network behaviour – which is provided through solutions such as smart meters, monitoring, controllers (demand, generation, microgrid, Advanced Network Management) etc.

The study highlighted 26 smart energy technologies, of which circa 21 have application in buildings. The identified technologies included the following 6 broad categories:

- Monitoring and sensors - Monitoring, data collection and in-built data analysis / controls
- Platforms / data analytics - Presentation and analysis of data on a digital platform
- Communications - Newer broadband technologies for transporting data
- Control - Technologies with a primary control function
- Storage - Electrochemical, heat and cold storage
- Response - Flexing energy consumption or output when signalled to do so

‘Blueprint for a post-carbon society: How residential flexibility is key to decarbonising power, heat and transport’[25]. OVO Energy and Imperial College London. September 2018.

The above paper suggests that smart home technologies could slash the cost of decarbonisation of the UK's energy sector by nearly £7bn a year through the widespread adoption of emerging energy "flexibility" technologies capable of better managing domestic supply and demand. The study analysed three different scenarios based on differing levels of deployment for residential flexibility technologies, such as smart electric vehicle (EV) charging and vehicle to grid systems, domestic batteries, and smart and electric heating systems. The scenario with the highest level of residential flexibility resulted in the lowest projected costs for energy system decarbonisation.

IEA Tracking Clean Energy Progress Report

The summary below relates to the IEA’s progress reporting concerning the ‘energy integration’ sector which includes energy storage, smart grids, demand response and digitalisation aspects.

International Trends in Energy Integration

While individual clean energy technologies are the building blocks to clean energy transitions, a variety of “energy integration” technologies – such as smart grids, energy storage, and hydrogen – will also need to play an increasingly important role to maximise the collective impact of individual technologies and bring the world onto an SDS trajectory. Some areas are seeing signs of progress, but overall, these increasingly crucial integration technologies need more innovation and policy focus.

Meeting the SDS goals will require scaling up of technologies that help different parts of the energy system work together. Though many of them are making progress, none of these important technologies is fully on track to meet the SDS goals

General Trends in Energy Storage (utility scale)

While battery prices fell by 22% from 2016 to 2017, continuing a very positive trend, additional utility-scale deployments for all storage technologies (excluding pumped hydro) remained flat in 2017 at around 620 MWh. This 2017 deployment rate is insufficient to meet the SDS target, which requires an additional 80 GW of overall storage capacity added by 2030. Additional policy support and ensuring a wider range of storage technologies become cost-effective are crucial.

General Trends in Smart Grids

Investment in smart grid technologies grew by 12% between 2014 and 2016 overall, but key areas such as smart distribution networks are lagging behind, with investment growing by only 3% in 2017. Progress in smart meter deployment is uneven across countries, with further regulatory change and new business models needed for smart grids to play their critical integration role in clean energy transitions.

Smart grids comprise a broad mix of technologies for modernising electricity networks, extending from the end-user to the distribution and transmission levels.

At the end-user level, smart grids can enable demand flexibility and consumer participation in energy systems, including through demand response, electric vehicle charging and self-produced distributed generation and storage.

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[25] https://www.ovoenergy.com/binaries/content/assets/documents/pdfs/newsroom/blueprint-for-a-post-carbon-society-how-residential-flexibility-is-key-to-decarbonising-power-heat-and-transport/blueprintforapostcarbonsocietypdf-compressed.pdf

Demand flexibility can increase the overall capacity of the system to host variable renewables while accelerating the electrification of heating, cooling and industry at lower costs. Deploying a physical layer of smart grid infrastructure – underpinned by smart meters – can help to unlock these benefits. Electric vehicles batteries will also play an increasing role in a smart grid and it is worth noting that the anticipated increase in electric vehicle use is likely to result in increased need for three-phase electrical supplies (e.g. in dwellings) to enable 'fast-charging' capability.

General Trends and Opportunities in Demand Response

The IEA's World Energy Outlook 2017 estimated that globally, the theoretical potential of demand-side response to be nearly 4,000 TWh per year, or more than 15% of total electricity demand. In the central scenario of the World Energy Outlook 2017, annual demand-side response potential is expected to increase to almost 7,000 TWh by 2040, the buildings sector leads future growth as demand for appliances and electric heating and cooling expands in Asia and Africa. Within developed economies, the electrification of heating and transport are major drivers of future growth. Smart charging of electric vehicles (EVs) uses charging (and discharging) of EV batteries to facilitate balancing of the power grid.

Policies to facilitate demand response are emerging in a number of regions, but only a small share of the full potential is being used today.

© OECD/IEA

Figure 10: Global demand response potential (source: IEA)

The IEA estimates that by 2040 almost 1 billion households and 11 billion appliances could participate in demand response programmes. While the majority of potential may lie in buildings, this potential can also be the most difficult to tap. This is especially the case in residential buildings, where participating in demand-side response programs may require behaviour change while offering limited economic benefits to households due to the small size of residential loads. As such, aggregation and automation of small scale demand-side response resources is often the most viable path to market for the residential sector.

The demand-side response potential in industry and large commercial buildings can be more accessible, as energy management systems optimize decisions to consume electricity or offer demand-side response services to the market.

Digitalisation / Connectivity as a key enabler

Digital connectivity is the key to expanding demand-side response into new sectors and realising a greater share of its total theoretical potential. By enabling the linking, monitoring, aggregation and control of large numbers of individual pieces of electricity consuming equipment, connectivity allows for matching demand to the needs of the overall system in real time. Smart meters, smart appliances, electric vehicles and load management software are therefore central to efforts to increase demand-side response resources.

Capitalizing on demand-side response potential also requires appropriate price signals and regulatory frameworks to incentivize participation. Retail tariff structures such as time-of-use pricing or real-time pricing can deliver the necessary price signals to consumers, while enabling aggregators and other demand-side resources to participate in wholesale energy, capacity and ancillary services markets can create the necessary environment to stimulate investment.

Demand-side resources active in markets today represent only the tip of the iceberg in terms of the total potential. Digitalisation presents an opportunity to unlock this enormous potential and significantly enhance grid flexibility. As prices for digital technologies continue to fall and electricity consuming equipment is increasingly connected and controllable, expansion of demand-side response becomes technically feasible and economically attractive.

Electricity consumers benefit from reduced electricity bills by providing demand response services, but even larger savings are realised on a system level. Digitally enabled demand response is often a more cost-effective and climate-friendly measure facilitating the integration of variable renewables than building new power plants or electricity storage. Rapid expansion will act as a key accelerator for the clean energy transition. Moving forward, government policy will need to provide clear rules and a long-term vision for increasing demand-side response resources.

8.4 Selected Market Insight

Smart Meters

Smart meter deployment has seen great strides in recent years in a few key regions. China is approaching full deployment, and Japan, Spain and France are poised to reach full rollouts over the next few years. The United States and the European Union as a whole have reached over half of the market.

Smart meter deployment has grown rapidly, with several countries poised to reach full rollouts over the next several years.

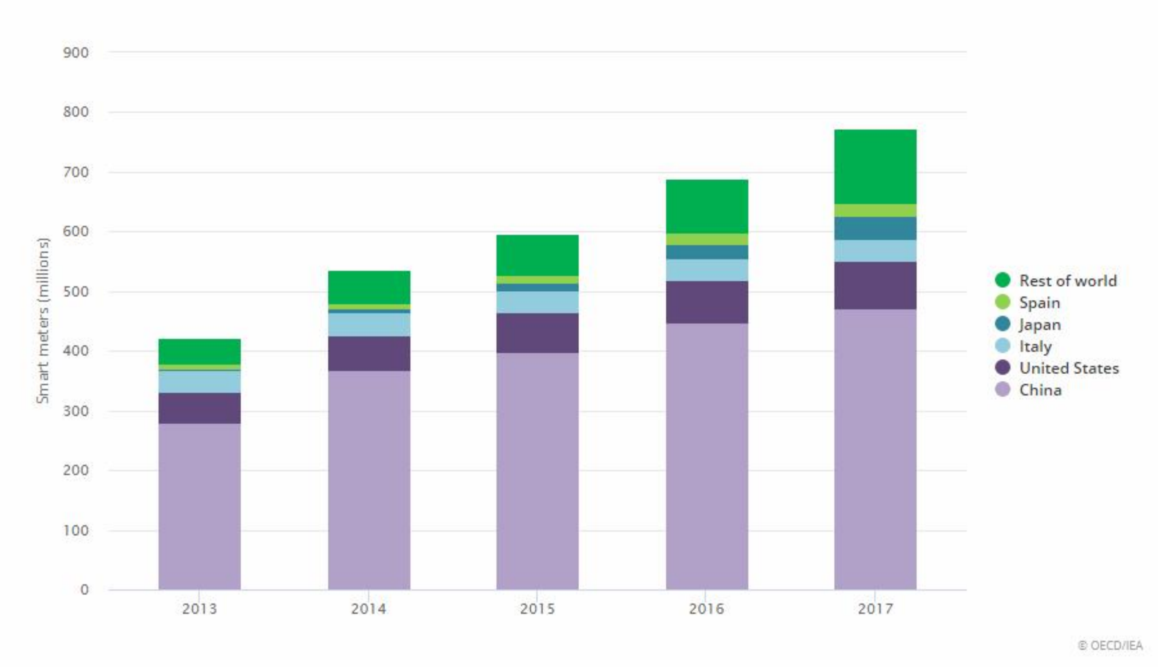
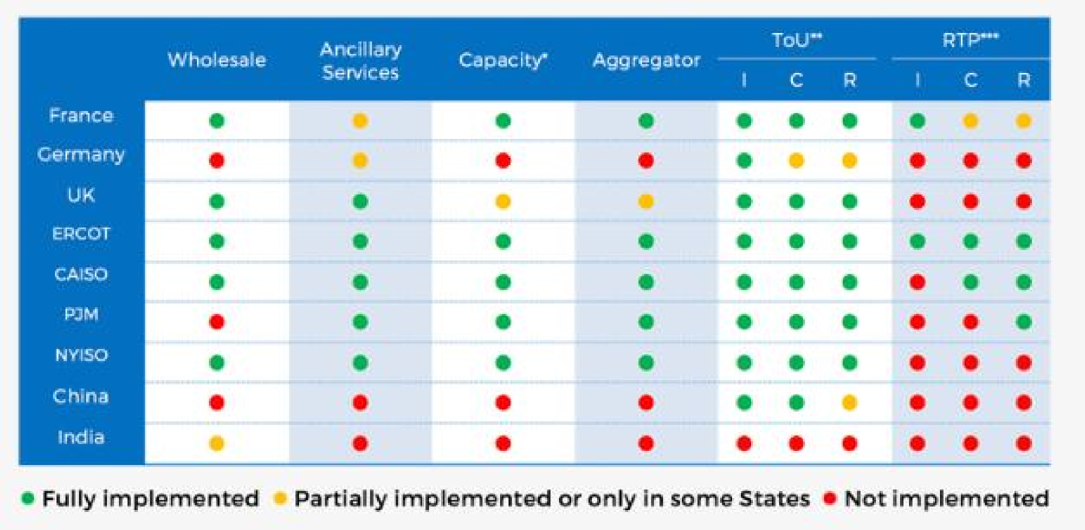


Figure 11: Global Cumulative smart meter roll-out (source: OECD / IEA)

Demand Side Response

Traditionally demand-side response has been confined to large-scale industrial consumers manually shedding demand in times of system stress. However the IEA report over 75% of the global potential in demand-side response lies in buildings, with space heating, water heating and air conditioning loads contributing the most. The thermal inertia of buildings and hot-water storage allows electricity demand from heating and cooling equipment to be shifted in time to suit the needs of the grid at low cost without compromising user comfort. Loads from appliances such as refrigerators and washing machines can also become demand-side response resources, facilitated by the growing market share of smart appliances.

Expanding demand-side response – beyond manual shedding of large loads – is a relatively recent phenomenon, with Europe and the United States currently leading growth. In several markets consumers can receive payment for various forms of short-duration “fast frequency response” to keep the grid in balance, larger volumes of “load shifting” to respond to changeable weather, or contracts for guaranteed changes to future consumption patterns.



	Wholesale	Ancillary Services	Capacity*	Aggregator	ToU**			RTP***		
					I	C	R	I	C	R
France	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟡	🟡
Germany	🔴	🟡	🔴	🔴	🟢	🟡	🟡	🔴	🔴	🔴
UK	🟢	🟢	🟡	🟡	🟢	🟢	🟢	🔴	🔴	🔴
ERCOT	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
CAISO	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢
PJM	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢
NYISO	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴
China	🔴	🔴	🔴	🔴	🟢	🟢	🟡	🔴	🔴	🔴
India	🟡	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴

🟢 Fully implemented 🟡 Partially implemented or only in some States 🔴 Not implemented

Figure 12: Current status of demand side response in selected electricity markets (source: IEA)

Notes: I, C and R refers to industrial, commercial and residential consumers. * Where no capacity market is present, day ahead reserves and other market products used to guarantee supply are included. ** ToU refers to time of use pricing. ***RTP refer to real time pricing including critical peak pricing where the time and price of peaks is not predetermined. ERCOT, CAISO, PJM and NYISO are major electricity interconnection regions within the United States.

8.5 Key Emerging Technologies

This section explores the networked or aggregated energy efficiency solution technologies (and to some extent the applications) that are most likely to offer potential for significant growth in the next 10 years based on emerging market trends, innovation and ongoing research activities. The analysis has considered solutions mainly within the more rapidly evolving domestic market, however the technologies and approaches will, in the main, also apply to non-domestic. It is worth noting that the list below is not definitive as this sub-sector continues to evolve.

1) ‘Connected / smart’ technologies and associated systems (including smart meters and appliances, digitalisation, data analytics, software development, local energy trading, etc.)

With the roll out of smart meters in every home in the 2020s, the domestic market for flexible demand could be significant. The National Infrastructure Commission recognise that this presents a significant opportunity for UK businesses however, without tackling regulatory and cultural barriers, it is unlikely that the full benefits offered by demand flexibility will be achieved. Scotland has significant expertise in data analytics and software development and this could be used to help manage energy demand seamlessly and showing what can be achieved can enable these capabilities to be marketed to the world.

A short introduction to a couple of innovative data-led solutions is presented below to demonstrate the evolving range of potential opportunities for aggregated energy efficiency solution providers:

- <u>Peer-to-peer energy marketplace</u> – Open Utility is “rethinking the way energy markets work”. Instead of buying electricity from big traditional power stations, their Piclo® peer-to-peer energy marketplace, in partnership with Good Energy, allows consumers to buy it directly. Piclo matches customers with local renewable producers, using smart meters to measure how much energy has been transacted peer-to-peer over the grid. Open Utility report that hundreds of renewable generators across Scotland, England and Wales are selling their locally sourced electricity from the sun, wind and rain directly to customers. In addition, it is claimed that whilst Piclo is currently only available to businesses, once smart meters are installed in every home, it should be available to everyone.

- Cloud-based services - Upside Energy has used innovation funding, including a grant from the Government's Energy Entrepreneurs Fund, to help support the development of algorithms to manage their distributed energy storage portfolio. Upside Energy has developed a cloud-based service that aggregates the energy stored in systems people and businesses already own, for example, uninterruptible power supplies (UPS) or solar PV systems. This creates a Virtual Energy Store™ that they can sell to the grid to help it balance supply and demand. They share the revenue they generate from these services with device owners and manufacturers, which helps consumers to decrease their energy bills.

2) Built environment related 'flexibility' solutions (including Demand Side Response)

There are expected to many emerging opportunities in this area which could, for example, range from demand side response of single and/or multiple energy vectors (e.g. electricity, heat and/or transport). Similarly solutions could focus on single technologies but across large numbers of properties (e.g. aggregated DSR via smart appliances or energy stores) or consider multiple DSR opportunities (e.g. heating, electricity and storage) in individual buildings or across building stocks.

A number of projects are presented below to demonstrate the evolving range of potential opportunities for aggregated energy efficiency solution businesses:

- FREEDOM project – this is demonstrating the ability of a hybrid heating system to switch between gas and electric load to provide fuel arbitrage and highly flexible demand response services. It is also demonstrating the consumer, network, carbon and energy system benefits of deployment of hybrid heating systems with an aggregated demand response control system. It is a collaborative project between electricity and gas networks (Western Power Distribution and Wales & West Utilities) with PassivSystems leading the day-to-day project management and designing the architecture of the smart switching system. This £5.2m innovation project consists of the installation of 75 hybrid heating systems (which comprises an exterior air source heat pump, a high efficiency gas boiler inside the home and a hybrid controls panel which enables switching between the two heat sources) in residential properties in Bridgend, South Wales.
- FLATLINE – Fixed Level Affordable Tariffs Led by Intelligently Networked Energy. In this project SERO Homes will deliver typical domestic energy consumers with set price heat and power fuel bills through an innovative integration and management structure between the collaborators' systems. Stable monthly bills will be possible by using a combination of domestic Demand Side Response and demand shifting (for both heat and electricity) across networked districts of homes, operating to control domestic appliances, heating, photovoltaic generations and battery storage in combination.
- Smart storage heating - VCharge, owned by Ovo Energy, is a smart storage solution that has been trialled in social housing to control electric storage heating to manage resident comfort and address fuel poverty in communities. The technology also supports the widespread adoption of renewable energy by providing valuable grid balancing services. VCharge heating controls are fitted to new or existing storage heaters and can be controlled via a smartphone. When combined with a smart tariff, residents reported dramatically improved comfort and lower bills, and greater control over their heating systems.

In addition, BEIS have recently had a number of research competitions with call topics including: Innovative Domestic DSR Competition; Smart Meter Enabled Thermal Efficiency Ratings (SMETER) Innovation Competition; Low Carbon Heating Technology Innovation Fund and Thermal Innovation Fund. More information of the calls and the projects receiving support is available via the BEIS website[26].

It is also worth noting that the evolution of aggregated DSR solutions is likely to lead to new and innovative business models (and related enabling technologies and platforms), that deliver ‘energy as a service’, or similar, to consumers. This could, for example, comprise a third party energy provider installing, owning and operating energy system assets within buildings giving them the opportunity to control energy use/demand (and thus create value from the assets via energy market revenues, typically via aggregators) whilst delivering pre-agreed energy and/or comfort provisions to the consumer / building occupants (e.g. heating comfort levels, electric vehicle minimum charge availability, or similar)

The above is likely to also present growing opportunities around complimentary and/or enabling technologies such as: smart meter data driven home/building energy management systems; next generation sensors; ICT platforms for managing data transfer and/or financial modelling/transactions; optimisation of energy assets; network integration; demand management; building and energy system monitoring, control and actuation, etc.

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[26] https://www.gov.uk/guidance/innovations-in-the-built-environment

9 Analysis of Scottish Capability

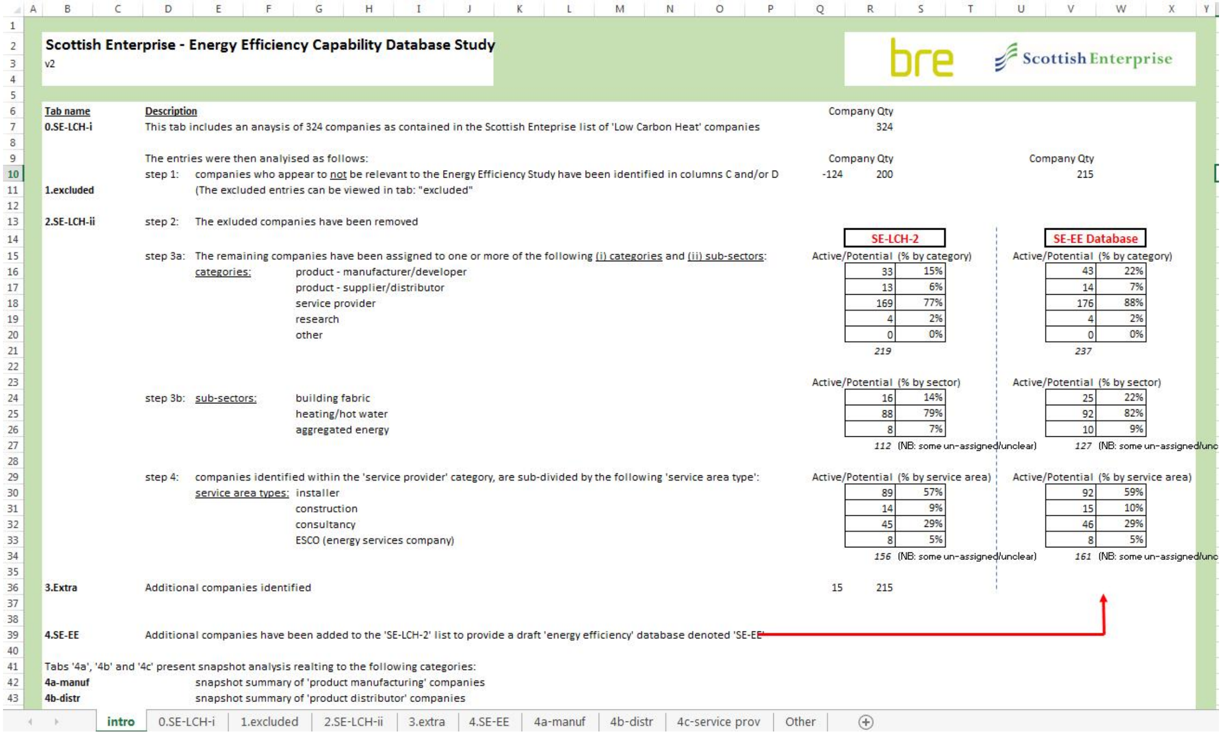
In this part of the study a database of Scottish based companies was developed and mapped against the (i) sub-sectors and sub-categories, and (ii) key emerging opportunities

9.1 Analysis of Scottish Capability Database

An initial list of over 324 companies was provided by Scottish Enterprise. BRE performed a profiling analysis on the companies to identify those that were relevant to the study before assessing which sub-sector(s) they appeared to be active in.

An online survey was also developed in order to supplement the desk based analysis of companies and to support market analysis and economic benefit analysis activities as reported later. Unfortunately, despite repeated efforts to drive engagement the survey only gave rise to 20 responses. This was unfortunately further hampered by the introduction of the General Data Protection Regulations.

As a result of the profiling and survey exercises 215 companies were identified as being relevant to the study.



Scottish Enterprise - Energy Efficiency Capability Database Study
v2

Tab name	Description		
0.SE-LCH-i	This tab includes an anaysis of 324 companies as contained in the Scottish Enteprise list of 'Low Carbon Heat' companies	Company Qty	324
	The entries were then analysed as follows:	Company Qty	
	step 1: companies who appear to not be relevant to the Energy Efficiency Study have been identified in columns C and/or D	-124	200
1.excluded	(The excluded entries can be viewed in tab: "excluded"		
2.SE-LCH-ii	step 2: The exluded companies have been removed		
	step 3a: The remaining companies have been assigned to one or more of the following (i) categories and (ii) sub-sectors:		
	categories: product - manufacturer/developer product - supplier/distributor service provider research other		
	step 3b: sub-sectors: building fabric heating/hot water aggregated energy		
	step 4: companies identified within the 'service provider' category, are sub-divided by the following 'service area type': service area types: installer construction consultancy ESCO (energy services company)		
3.Extra	Additional companies identified	15	215
4.SE-EE	Additional companies have been added to the 'SE-LCH-2' list to provide a draft 'energy efficiency' database denoted 'SE-EE'		

Company Qty 215

SE-LCH-2

Active/Potential	(% by category)
33	15%
13	6%
169	77%
4	2%
0	0%
219	

Active/Potential	(% by sector)
16	14%
88	79%
8	7%
112	(NB: some un-assigned/unclear)

Active/Potential	(% by service area)
89	57%
14	9%
45	29%
8	5%
156	(NB: some un-assigned/unclear)

SE-EE Database

Active/Potential	(% by category)
43	22%
14	7%
176	88%
4	2%
0	0%
237	

Active/Potential	(% by sector)
25	22%
92	82%
10	9%
127	(NB: some un-assigned/unc

Active/Potential	(% by service area)
92	59%
15	10%
46	29%
8	5%
161	(NB: some un-assigned/unc

Tabs '4a', '4b' and '4c' present snapshot analysis realting to the following categories:
4a-manuf snapshot summary of 'product manufacturing' companies
4b-distr snapshot summary of 'product distributor' companies

Figure 13: Extract of the Scottish Enterprise – energy efficiency company database

The following process was then applied to the 215 companies to: (i) categorise the nature of the companies; (ii) analyse the number of company deemed to be active within, or offer cross over potential, each of the three energy efficiency sub-sectors; and (iii) map existing capability against the key potential emerging opportunities highlighted by the study. The analysis was informed by a review of the company website and/or using in-house knowledge of company capability.

Company type

Companies were assigned to one or more of the following categories:

- Product * - manufacturer/developer
- Product * - supplier/distributor
- Service * provider
- Research
- Other

(* Products are considered to be assets which are produced as the result of a research and development process, and can be manufactured (hardware or software). Services are considered to be activities which can aid the development, manufacture, installation and/or operation of products as part of a system. Services may be direct (such as a product design service) or indirect (such as a market analysis service).)

The analysis presented the following results:

	Active/Potential	**% by sector**
Category	**(nr)**	**(%)**
product - manufacturer/developer	43	18%
product - supplier/distributor	14	6%
service provider	176	74%
research	4	2%
	237	(NB: some un-assigned/unclear)

Table 7: Number and relative percentage of businesses by category

An additional sub-division of the ‘service provider’ category was undertaken in order to provide additional insight to the activities of the service providers. Companies were therefore assigned to one or more of the following ‘service area types’:

- Installer (e.g. mechanical or electrical systems, microgeneration, etc.)
- Construction
- Consultancy
- Energy Services Company (ESCO) or similar

The analysis highlighted the following:

	Active/Potential	% by service area
Service area types	**(nr)**	**(%)**
installer	92	57%
construction	15	9%
consultancy	46	29%
ESCO (energy services company)	8	5%
	161	(NB: some un-assigned/unclear)

Table 8: Number and relative percentage of ‘service providers’ by ‘service type area’

Capability by ‘sub-sector’

Companies were also assigned to the three sub-sectors as per below. In some cases companies were assigned to more than one sub-sector.

- Building fabric
- Domestic heating / hot water
- Aggregated energy efficiency services

The analysis highlighted the following:

	Active/Potential	% by sector
Sub-sectors	**(nr)**	**(%)**
building fabric	25	20%
heating/hot water	92	72%
aggregated energy	10	8%
	127	(NB: some un-assigned/unclear)

Table 9: Number and relative percentage of businesses by sub-sector

9.2 Current Capability within identified 'Key Emerging Opportunity' Areas

Sections 6.3, 7.3 and 8.5 have highlighted a number of potential key emerging opportunities in each of the three sub-sector. For ease of reference these are summarised in the table below.

	Building fabric and related technologies
F1	Factory manufactured / off-site constructed fabric elements or systems
F2	New, high-performing, insulation products
F3	New/improved insulation retrofit techniques
F4	Circular economy / embodied energy of building fabric components

	Domestic space heating (and hot water) technologies
H1	Heat Pumps (including high temperature heat pumps, hybrid heat pumps and gas heat pumps)
H2	Other low carbon heat technologies
H3	'smart' heating controls / heat storage / demand response technologies

	Network or aggregated energy efficiency solutions
A1	'Connected / smart' technologies and associated systems (including smart meters and appliances, digitalisation, data analytics, software development, local energy trading, etc.)
A2	Built environment related 'flexibility' solutions (including Demand Side Response)

Table 10: Summary of 'key emerging opportunities'

Subsequent analysis of each of the three distinct 'sub-sector' lists was then undertaken to identify (i) companies who were deemed to have current capability in the 'key emerging opportunity' areas, and (ii) companies deemed to have related technologies or capability that could offer 'potential' capability in the respective area.

The results of this analysis is presented below. A colour coding system is used to categorise the capability as explained by the legend below. The following should also be noted when interpreting the results:

- The analysis focussed on the companies listed in the database developed via the project (as outlined above. As a results it is not exhaustive and as a result it may exclude other Scottish companies that are currently active and/or offering potential within the emerging areas.
- Companies identified as 'potential?' included companies within the database that have products, technologies, etc. that are related to the respective key emerging areas but typically present more 'traditional' systems or technologies (e.g. traditional hot water cylinder manufacturers, traditional timber frame manufacturing companies, or similar).
- This analysis includes a small number of non-Scotland based companies given that the parent database included some non-Scotland based companies. The colour rating of the 'active' companies within both 'H3: smart heating controls / storage / demand response' and 'A2: built environment related flexibility solutions' categories are most significantly influenced (circa 50%) by the non-Scottish company content.

Ref:	Nr of companies
-	0
🟥	1-5
🟧	6-10
🟩	>10

Table 11: Legend for the ‘Mapping of capability/potential in identified ‘key emerging areas’

Active	**Potential?**	**Combined**		
				Building fabric and related technologies
🟧	🟥	🟩	F1	Factory manufactured / off-site elements or systems
🟥	-	🟥	F2	New, high-performing, insulation products
🟥	-	🟥	F3	New/improved insulation retrofit techniques
🟥	-	🟥	F4	Circular economy / embodied energy of fabric components
				Domestic space heating (and hot water) technologies
🟥	-	🟥	H1	Heat Pumps
🟥	🟥	🟧	H2	Other low carbon heat technologies
🟧	🟧	🟩	H3	‘smart’ heating controls / heat storage / demand response
				Network or aggregated energy efficiency solutions
🟥	-	🟥	A1	‘Connected / smart’ technologies and associated systems
🟧	-	🟧	A2	Built environment related ‘flexibility’ solutions

Table 12: Mapping of capability/potential in identified ‘key emerging areas’

The analysis highlights the following in relation to the key emerging opportunities identified in the study:

- Scottish capability is generally low in all of the identified areas.
- There is a small number of additional companies whose technologies, products and/or systems may offer additional potential in the evolving areas.
- The highest level of current capability / ‘clustering’ is in areas F1, H3 and A2 and additional potential appears to be relatively high in areas H2 and H3.

The full analysis, as outlined above, and the corresponding database of companies has been provided to Scottish Enterprise in Excel spreadsheet format as part of the study.

10 Economic Benefit Analysis

This stage aimed to provide an assessment of the energy efficiency sub-sectors in Scotland and comment on its importance nationally and internationally, it's potential for future growth and key issues that could foster or constrain this growth. The assessment was informed in part by interviews with key businesses and organisations based in Scotland, surveys of other firms in the Energy Efficiency sector, and by quantitative modelling. Key tasks included:

- Telephone interviews of major Account Managed businesses and stakeholders
- Online survey of businesses in the energy efficiency sector and analysis of survey results
- Modelling the impact of the Scottish energy efficiency sector

Consultation question-sets (see Appendix E) were developed to ensure that the business and stakeholder consultations were conducted in an appropriately structured and consistent manner.

Each stage is discussed in turn below.

10.1 Business and Stakeholder Consultation

Key findings were as follows:

Technology

- Repeated comments to de-carbonise the electricity grid and use as the primary heat source.
- Scalability is important.
- Provide battery storage for load management.
- Currently bias towards gas as it is too cheap. The relatively low price of gas has hindered progress and there has been an overweighting of gas as being carbon efficient. The current regulatory system is irrationally biased towards gas and this is based on old and out of date data.

Like for Like Materials

- Unbiased and accurate material testing facilities are required.
- Foreign, cheap and underperforming products are a threat.
- UK manufactured products or materials that perform to specification should be seen as a strength.

Buy Scottish!

- Endeavour to use Scottish technology. Scotland should be head of the supply chain, however this is not always possible.
- Importance of establishing a local supply chain as it makes products inherently greener.
- European and World leading technology for hydrogen generation and reuse, but not commercially viable. Needs scalability. Main hydrogen equipment from Canada and Italy.

- Competition from Germany, Japan and South Korea (as a result of de-nuclear power post Fukushima) and from the United States (California).

Economic Challenges

- Investment – but where from? Public or private.
- BREXIT has reduced investment
- Currency exchange rates are fluctuating and has stifled competition.
- Market conditions.
- Political challenges.
- Scottish Enterprise seen to be chasing Foreign Direct Investment and should be supporting home grown business. This however was raised as an issue by a Foreign Owned Company!

Policy and Legislation

- Legislation needs to be increased to improve thermal efficiency. Seen as a key driver.
- No firm legislation, no subsidies and no training for heat pump technology. Skills shortage, cost is high and the technology is complex.
- "Fat Cat" companies are regulating energy prices. Call to re-nationalise!
- 8 million homes in Scotland without insulation.
- Councils and Housing Associations slow to adopt change.
- EESSH – Energy Efficiency Standard for Social Housing 2020/2032 is legally binding.
- Financial support would be good.
- In Germany 40% of new-build properties are installing heat pumps. In Scotland hardly any.
- Most important is the support for installers, they need to be given a reason to change supported by new skills through a combination of apprenticeships and training.
- The current regulatory approach does not sufficiently deal with the practical implementation of the scheme.

Innovation

- Modular and off-site construction provides a growing opportunity to improve quality and performance.

Infiltration

- Balance between draughty buildings having higher energy costs and well-sealed buildings causing health issues.

Skills Shortage

- More government legislation is required to help overcome skills shortages.
- A skills base already exists in Scotland (renewables) which can be adapted.

- Should not be ignored that what the customer perceives as “bad workmanship” has a marked impact on the uptake of the technology and adequate training is key to the effectiveness of the products.
- Some resistance to change within the trades (some fail to see the value of the new technologies).
- Businesses have had to develop their own in-house training (which they pay the bill for) to upskill installers and meet demand for the new technologies. New apprenticeship levy for larger businesses could provide funding for training.

Profile Raising

- There is need for more promotional activity and a body to coordinate sector-based activity.

10.2 Stakeholder Consultation

Key findings were as follows:

Policy, Procurement and Legislation

- The 15 to 20 year cross-party support for this initiative is seen as good and gives businesses a long-term goal to focus on.
- What is the Policy? Should be firm and aligned. Businesses can then develop capability and plan for the future.
- Procedures and processes for bidding work is cumbersome. Many companies are poor at bid writing, do not seek feedback when unsuccessful, do not use expensive bid-writing companies and are often put off by excessive levels of Professional Indemnity and Public Liability Insurances. Best practice guidance and simpler processes would be welcome.
- Health Facilities Scotland not able to borrow money, seek grants to develop ideas or sell on overcapacity. The public sector suffers from inertia and is risk averse.
- Technology costs must come down.
- Consider total life cycle costs and efficiency of electricity at the point of use.
- Nothing is being done to reduce the price of electricity, currently running at four times the price of gas. However noted that UK has the lowest electricity costs in Europe.
- Legislate and Compel. Regulation as the driver.
- Government Departments are not coordinated.
- To achieve EPC band C by 2040 requires the promotion of a suite of measures through a mandated and qualified delivery agent.
- An Ombudsman needs appointing.
- The proposed energy policy only targets 25% of the housing stock, leaving 75% to the private owner and rented. Government reluctant to impose a minimum standard on owner occupiers and private landlords.

Technology

- De-carbonise electricity through renewable generation.
- There will be a move to “energy as a service” rather than a device.
- Without some form of Dynamic Time of Use Dependent Tariffs, the only real use for smart meters is for taking remote meter readings. Behaviour changes will not reduce energy consumption.
- Smooth out the demand curve and match demand.
- Energy efficient technology can be prohibitively expensive, for example Heat Pump compared to a boiler installation.
- All electric heating considered more efficient, only if low or zero carbon sourced.
- Electrification of transport and heating.
- Retro-fitting insulation is a big challenge due to very old building stock and potential for aesthetic or material damage.
- Biomass schemes are out, CHP are in, with Heat Pumps next.
- Building regulations provide a conflict between engineering performance, acoustics and aesthetics.

Quality Assurance

- QA is a big issue. It needs to be stressed that poor workmanship affects the effectiveness of the retrofit measures therefore the quality standards are very important and workers need to be sufficiently skilled to carry out a professional, reputable job.
- There is a need for an Ombudsman to be appointed for installers and a strict code of practice be adopted in case of redress and encourage more of a consumer-led focus.
- Need to be assurances on quality, certificates, inspection during installation, managing the retrofit, as well as ensuring skilled work of a high standard is carried out.
- The Quality assurance process needs to support, rather than make it harder, for businesses to participate and paperwork needs to be simple.

Social Challenges

- Fuel poverty – eat or heat? Energy is relatively cheap, however a change in policy to alter energy use behaviour may harm and disadvantage those people on very low incomes.
- Rural areas are a challenge. Strong communities and participation. Heat pumps are possible, however the electricity supply network is not strong enough.
- Social landlords have a high cost to bring up to standard whilst under pressure to keep costs down.

Economic Challenges

- Brexit
- The European Cooperation in Science and Technology (COST) will disappear under BREXIT.
- No Strategic funding in place and needs securing and/or tax breaks.

Supply Chain and Skills

- It has been stated that the supply chain has the skills, however there is a need for general up-skilling.
- Lack of installers for the retro-fit sector.
- There are poor quality installers and there should be a register of approved tradesmen. The Green Deal was not a positive experience in terms of finding suitable contractors.
- Good companies could diversity into this sector.
- Strong skills in the renewables sector.
- Delivery of training to upskill established tradesmen means them taking time away from work which has a financial impact.
- These skills need to be at all levels, not just tradesmen the sector needs planners and renewables experts for example.
- EPC banding could create a huge amount of work. The hand-skills are there, however the technical knowledge is missing. Training for insulation installation is provided by the manufacturers. There should be investment into qualifications remote from the manufacturers, such as College based training to increase technical knowledge.
- There is a lack of capacity outside of the Central Belt.
- If a business pipeline is established, there is an opportunity to gear up apprentices to fill the gap.
- The workforce is ageing.
- BREXIT is creating a skills vacuum with migrant works returning to Eastern Europe.
- Plumbing and heating apprenticeships are taken up, however without the energy efficiency modules.
- Inward investment for the manufacture of wood fibreboard should be actively encouraged.
- Insulation is a self-regulated industry, which is an unsatisfactory situation.
- Stronger regulation and Quality Assurance for inspection, testing and a skilled workforce.
- For combined heat and power (CHP) there is a lack of knowledge and shortage of skills. Considered better to improve energy efficiency first before introducing any new energy technology.

Profile Raising

- Promote and raise public awareness generally.
- Raise awareness of business opportunities to encourage the development of the workforce.
- If policy drives behaviour then a similar response to recycling could be achieved.
- Orkney case study.
- Look overseas for inspiration e.g. Danish Energy Agency.
- Scottish Government should produce regular updates on progress. Public information campaigns.

10.3 Online Business Survey Analysis

Key findings from the online survey were as below. Owing to the low number of respondents (20 number), it should be noted that the issues highlighted below may not be representative of the sector as a whole.

Overview

A web survey (see Appendix D) was carried out of those firms in the Energy Efficiency sector (Account Managed and non-Account Managed businesses). The web survey sought evidence from businesses in the sector on the following:

- Location of headquarters
- Number of facilities/offices in Scotland
- Turnover and employment numbers
- Performance over the past three years on turnover, profit and employment
- Details of main products and/or services
- Key current markets (product/service and geographic)
- Opportunities (i.e. geographical, sectors, new products/services, product diversification, expansion of current markets due to government legislation etc.)
- Barriers to expansion
- Strategy to take advantage of the opportunities and to overcoming the barriers
- Skills issues, gaps, requirements
- Accessing supply chains including public sector procurement
- R&D and Innovation
- Access to finance, funding and investment
- Export activities (i.e. current markets, future opportunity markets, export sales volume and as percentage of sales)
- Forecast performance for next three years.

The results described below are based on 20 completed surveys. The survey used a mix of straightforward responses on figures, technology/service areas, performance, and international trade and planned developments with more open responses to barriers, new markets, reasons why these are being targeted and main companies in their supply chain. The responses to open questions provided a wealth of information which is used along with the evidence base to identify and develop potential interventions.

Survey Results

Type and Age of Business

Eighteen of the 20 responses (90%) were from Private Limited Companies, one was from a Public Limited and there was one not-for-profit respondent. Fifteen respondents (75%) had their headquarters (HQ) in Scotland, whilst four of the other five firms had their HQ in the UK (three in England and one in Northern Ireland). The remaining business was a Japanese multinational, headquartered in Tokyo. Just under half (45%) of responses were from businesses that were formed during the past decade, including one business that started up earlier in 2018. Four firms had been trading for more than 35 years, with the oldest business formed in the late 1970s.

Business Size and R&D Intensity

All bar two of the businesses were SMEs, including twelve microbusinesses (firms with fewer than 10 employees). At the other end of the scale, there were two responses from firms with more than 250 employees. Sixteen businesses provided evidence on their annual turnover, seven of which generated below £250,000 per year, whilst five firms reported more than £1 million annual turnover. Some 80% of respondents employed staff who were actively engaged in R&D: ten firms had between one and five people working on R&D activities, whilst one firm had an R&D team of more than 50 employees. R&D intensity varied greatly between the businesses: one in five firms invested less than 1% of their Scottish turnover in R&D, whilst 40% of firms reported investing more than 20% of Scottish turnover in R&D.

Nature of the Businesses and Recent Performance

The businesses covered a range of activities. The most commonly selected business activities[27] were: consultancy service providers (e.g. design, energy/building assessment, innovation, etc.) and product suppliers/distributors of domestic space heating and water hearing products.

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[27] Respondents could select more than one option.

Type of Activity	Number of Firms
Service providers - consultancy (e.g. design, energy/building assessment, innovation, etc.)	8
Product suppliers/distributors of domestic space heating and water hearing products	6
Firms carrying out research in the domestic space heating and water heating sector (e.g. products, processes, etc.)	5
Manufacturers of domestic space heating and water heating products	5
Service providers of construction or installation activities	4
Manufacturers of building fabric energy efficiency products	3
Manufacturer of aggregated energy efficiency products.	2
Source: Innovas	

Table 13: Business activities

Half of firms intended to target new sectors, including dairy farms and holiday\caravan parks, materials research, marine (shipbuilding), oil & gas and wind industries, building environmental control for vulnerable people in the community, aggregated energy efficiency products, energy networks (such as Smart Grids storage and controls), energy storage, commercial construction projects and tenement building energy efficiency.

Half of respondents reported growth or strong growth (greater than 20% per annum) in both turnover and employment during the past three years, with one-quarter of firms reporting static turnover and employment. A slightly smaller number of respondents (40%) reported growth/strong growth in profits, although the same percentage reported static profit. Three firm saw profits fall during this period, whilst some 60% of firms reported increased investment.

Supply Chains

Most firms sourced most of their inputs to production from within Scotland, the rest of the UK or the EU. All firms sourced at least some inputs from other Scottish businesses, and 35% of firms sourced more than 50% of their inputs from within Scotland. Two firms sourced more than half their inputs from the rest of the UK and just one firm had more than half of its supply chain based in the rest of the EU. Two firms had a majority of inputs from outside the EU. Just two firms had no UK-based suppliers. Firms do not expect Brexit to have much if any impact on the location of their suppliers. All bar one firm expect the proportion of their inputs from Scotland, the rest of the UK and the rest of the EU to either increase or stay the same. Just one further firm expected the proportion of non-EU sourced inputs to fall.

Despite the high propensity of Scottish firms to source supplies from within Scotland, half of firm stated that they do face barriers in accessing resources from the Scottish supply chain. The reasons tended to be specific to the firm and the markets they operate in, and included:

- More cost-effective to source some solar heating equipment from the Far East
- Challenges in determining IP ownership for public-private innovation collaborations
- Skills shortages in payment practices and audit processes within the construction industry
- Lack of metal and materials manufacturing capabilities in Scotland.

Key Customers and Markets

Current Customers and Markets

Key customer sectors served by the businesses are shown below. Three of the top four customers were in the built sector, including domestic and non-domestics buildings.

Sector	Number of Firms
Non-domestic buildings (refurbishment/retrofit)	12
Industry and commercial sector	11
Non-domestic buildings (new build)	10
Domestic buildings (new build)	8
Energy/energy networks	7
Manufacturers of building fabric energy efficiency products	3
Manufacturer of aggregated energy efficiency products.	2
Source: Innovas	

Table 14: Key Market Sectors

The main customers by type of customers were domestic social housing providers, developers, commercial clients and local government.

Customer	Number of Firms
Domestic social housing providers	11
Developers	11
Commercial clients (e.g. offices, retail)	10
Local government	10
Industrial clients (e.g. manufacturing, chemicals, oil & gas, food & drink)	6
Further and Higher Education	6
Other public sector organisations	6
Owner occupiers	6
Source: Innovas	

Table 15: Key customer types

Three-quarters of businesses had more than 50% of their sales in Scotland, with six firms operating solely in Scottish markets (i.e. 100% of sales in Scotland). Six firms exported to other countries in the EU, although just one firm had more than 20% of sales in the rest of the EU. Four firms served markets outside the EU. Overall, just six of the 20 respondents served export markets. Of those firms trading internationally, the following were the most important export locations:

Location	Number of Firms
Western Europe (including Nordic countries)	6
South America	2
Central/Eastern Europe (including Turkey)	1
China	1
Asia (excl. China)	1
Source: Innovas	

Table 16: Key export locations

Future Customers and Markets

All bar one firm intends to access new overseas markets in the next three years, and the range of target markets was very varied.

Location	Number of Firms
Australasia	4
Africa	3
Middle East	3
Western Europe (including Nordic countries)	2
Central/Eastern Europe (including Turkey)	2
China	2
Asia (excl. China)	2
South America	2
Source: Innovas	

Table 17: Intended export locations

A handful of firms had drawn on market research to inform their future export plans. Sources of evidence referenced were Scottish Development International (SDI) and Solrico (Solar Thermal World). Of those firms not currently exporting, all would consider seeking to access new markets in future. Several challenges in accessing new markets were highlighted, both by existing exporters and those currently only operating in Scotland or the rest of the UK. These were: establishing local partners; communication, marketing and shipping costs; the intensity of competition; and like firms in many export-intensive sectors, the uncertainly about UK future trading arrangements with the EU and also non-EU countries once the UK leaves the EU.

All firms expressed an interest in taking part in overseas collaborative ventures, with joint ventures, technical cooperation and technology licensing being the top three types of ventures firms were interested in.

Type of Collaboration	Number of Firms
Joint ventures	10
Technical cooperation	9
Technology licensing	8
Manufacturing	6
Central/Eastern Europe (including Turkey)	5
R&D opportunities	3
Foreign aid missions	2
Source: Innovas	

Table 18: Overseas collaboration opportunities

Sector Drivers

A range of technology drivers were identified that could impact upon businesses over the next five years:

- Materials development, including improved insulation materials and increasing cost of production
- Smart Technology and Grid Control
- Collaboration, planning, clean payment practices which do not require the SME to fund projects
- Integrated demand management, cloud based services, big data and pervasive internet (the so-called Internet of Things)
- Decentralisation of the power supply and local buying / production of renewable energy
- Cheaper more efficient hydrogen systems
- Demand and support for renewable heat technologies.

Key challenges identified were:

- Increased cost of imported materials inputs
- Lack of a level playing field between renewable technologies with regard to subsidies
- Complexity/bureaucracy related to public sector procurement
- Government regulations regarding electric heating
- Excessive costs associated with ongoing upgrades/changes to CAD software
- Skills gaps
- Marketing (i.e. understanding the target audiences in different countries)
- Lack of available government funding (Faraday funding just seems to be aimed at electric storage) and confusion in the market over how schemes operate and what technologies/sub-sectors they apply to.

- Loss of the Renewable Heat Initiative (RHI) and a lack of public awareness of renewable heat technologies
- Government does not fully understand the potential of hydrogen for storage.

Key opportunities identified were:

- Use of building simulation
- Improvements in renewable technology (but need to raise awareness of renewable technology and likely higher cost of energy from more traditional sources)
- Stronger legislation driving market demand
- Adoption of energy efficient technologies as an alternative to back up diesel generation
- Funding of PhDs or other knowledge related activities, such as Knowledge Transfer Partnerships (KTPs) to develop renewables alternatives to electric storage
- International trade agreements post-Brexit (if these are negotiated to the UK's advantage)
- Increased interest in energy efficiency, product selection in retrofit and new build markets.

The most important regulatory drivers were identified as:

- Scotland's Energy Efficiency Programme (SEEP)
- Climate Change (Scotland) Act 2009
- Home Energy Efficiency Programmes
- CRC energy efficiency scheme
- Home Energy Efficiency Schemes
- EESSH 2020 and EESSH 2032
- Building and heat regulations
- Standard Assessment Procedure
- Renewable Transport Fuel Obligation.

Trade Association Membership

There does not appear to be any one dominant trade association. Businesses were members of a whole range of membership and trade bodies/associations. The main advantages of membership include provision of advice, capability audits and training, lobbying capabilities, networking and knowledge sharing. Membership bodies referenced included:

- Insulation Manufacturers Association
- Hot Water Association
- Heat Pump Association
- Renewable Energy Association
- Scottish Renewables
- Solar Trade Association
- Energy Action Scotland
- Heating & Hot water Industry Council
- Scottish Energy Association
- Society of Maritime Industries
- FPAL
- Constructionline
- Scottish Fuel Cell and Hydrogen Association
- Renewable Energy Consumer Code
- Scottish Solar Energy Group
- British Property Federation
- Nuclear Industry Association
- Federation of Master Builders
- National Blown Bead Association
- British Standards Institution.

Future Opportunities and Challenges

Three-quarter of respondents expect growth or strong growth (greater than 20% per annum) in both turnover and employment during the next three years, with only two firms anticipating static or declining turnover and employment. More than half of respondents expect growth/strong growth in profits, although around one-quarter expect static or declining profits. The outlook for investment appears more mixed, with half of respondents planning to increase investment, but one-quarter planning to keep investment levels as they are now or to reduce them.

Key geographical growth markets identified were: Scotland and the rest of the UK, EU, North America, India, China, Japan and Australia.

Key product/services markets identified were: building simulation, solar thermal water and space heating; supply to the new build and the social housing sector; manufacture of bespoke modular frames; building energy management; lighting & heating control; wellbeing management; internal wall insulation systems; fuel cell generators; UniQ heat energy storage products; SHARC, PIRANHA and integrated design support; battery storage; solar thermal as part of the renewable heat energy mix (which should gain more interest as energy prices rise).

A range of common challenges that could constrain growth were identified. The most commonly referenced challenge was political uncertainty (relating in the UK to Brexit, but also including global geopolitical issues), whilst industry/product standards/regulation (which will vary from country to country) were the other main policy-related challenge. Market conditions, distance from growth markets were the main market-related challenges, whilst difficulties accessing finance to support growth reflects difficulties in securing funding from both private sector and public-sector sources.

Challenge	**Number of Firms**
Political uncertainty	9
Market conditions	8
Standards and regulations	8
Distance from markets	7
Lack of finance for business growth	7
Intensity of competition	6
Lack of resource for R&D	5
Difficulties in recruiting staff with scientific/technical skills	4
Need to develop business management skills	4
Other staff/recruitment issues	4
Source: Innovas	

Table 19: Constraints on growth

Business Support Requirements

A wide range of business support requirements were identified by respondents. The most commonly cited requirements were related to developing collaborative partnerships (with other businesses and research institutions), which in part reflects the strong desire already mentioned among many firms to seek and exploit overseas collaborative opportunities, but also perhaps a lack of awareness of how to develop the necessary partnerships.

Location	Number of Firms
Developing collaborative partnerships with other businesses	11
Developing collaborative partnerships and agreements with research institutions	8
Funding for projects	7
General business financing	6
Innovation and R&D	6
Awareness of overseas energy policies and standards	6
Marketing information and/or advice	6
International trade	4
Accessing overseas procurement opportunities	3
Independent assessment/validation of product performance	2
Networking	2
Skills & training	1

Source: Innovas

Table 20: Business support requirements

Additional specific needs stated were:

- Advice on how to access markets/frameworks
- Alternative routes for innovation/inventor funding that doesn't involve competitions (e.g. Innovators in Residence programmes)
- More information on safe trading internationally, as when international trading is new, it is difficult to know where to trade and who it is safe to trade with (including delays in payments)
- Country specialist recruitment (e.g. Business Manager in China)
- Assistance in networking outside UK and establishing distribution or marketing agreements.

10.4 Quantitative Scale of the Sector

Introduction

This section provides estimates of Scottish energy efficiency sector GVA and employment for 2018 and projections of future growth under a range of scenarios. As noted already, 215 Scottish based companies have been identified as having energy efficiency expertise. However, there is no other published data on the sector in Scotland and so a number of assumptions have had to be made based upon the most appropriate data available (i.e. the most closely matching sector definition and most relevant spatial levels) from other sources. These are described below.

Assumptions

The modelling has been informed by the following assumptions.

Variable	Assumption	Rationale	Source
Annual GVA growth rate	Baseline 7.0% per year	This is the average annual rate of growth experienced for the UK low carbon & renewable energy sector between 2013-16 (the most recent year for which data are published)	The Size and Performance of the UK Low Carbon Economy 2010-14; and UK Environmental Accounts: Low Carbon and Renewable Energy Economy Surveys 2015 and 2016
Annual jobs growth rate	Baseline 3.5% per year	This is the average annual rate of growth experienced for the UK low carbon sector between 2013-16 (the most recent year for which data are published)	The Size and Performance of the UK Low Carbon Economy 2010-14; and UK Environmental Accounts: Low Carbon and Renewable Energy Economy Surveys 2015 and 2016
Number of jobs per firm	Average firm size of 38 employees (full-time equivalent) in 2018	Based on average firm size (by FTE jobs) most recently recorded for firms in the low carbon heating & cooling sector in Scotland in 2004 (33), projected forward at growth rate of 3.5% per year subsequently.	Scottish Enterprise Company Capability Analysis – Low Carbon Heating and Cooling and Water and Wastewater Sectors (2014)
GVA per job	£107,751 in 2018	Estimated GVA per job figure for the UK low carbon & renewable energy sector in 2018 based on previous GVA and employment data published and assumption of baseline growth rates continued between 2016 and 2018	The Size and Performance of the UK Low Carbon Economy 2010-14; and UK Environmental Accounts: Low Carbon and Renewable Energy Economy Surveys 2015 and 2016

Table 21: Quantitative modelling assumptions

Current and Future GVA and Employment

Drawing on the data sources noted above and applying the assumptions derived from these sources, the estimated size of the Scottish Energy Efficiency sector in 2018 is:

- Number of firms = 215
- Number of jobs per firm (FTE) = 38[28]
- Total sector jobs (FTE) = 8,213[29]
- GVA per job = £107,751
- Totals sector GVA = £885.0 million

Scenarios

Six scenarios for future growth of Scottish Energy Efficiency sector GVA and employment up to 2026 (i.e. ten years from the most recent year for which UK level data are published for the low carbon & renewable sector) have been developed. These scenarios are as follows:

- ‘Business as Usual’ scenario: assumed annual growth in GVA continues at 7.0% per year and employment at 3.5% per annum up to 2026.
- ‘Five Star Policy’ scenario: assumes policy interventions generate an additional 3 percentage points in growth in GVA per year (i.e. 10.0% per year) and an additional 1.5 percentage point growth in employment (i.e. 5.0% per year) compared to the baseline projection, up to 2026[30].
- ‘Four Star Policy’ scenario: assumes policy interventions generate an additional 2 percentage point in growth in GVA per year (i.e. 9.0% per year) and an additional 1 percentage point growth in employment (i.e. 4.5% per year) compared to the baseline projection, up to 2026.
- ‘Three Star Policy’ scenario: assumes policy interventions generate an additional 1 percentage point in growth in GVA per year (i.e. 8.0% per year) and an additional 0.5 percentage point growth in employment (i.e. 4% per year) compared to the baseline projection, up to 2026.
- ‘Sector Slowdown’ scenario: assumes modest slowdown in sector growth and that policy interventions are unsuccessful in stimulating growth, resulting in a 1 percentage point reduction in growth in GVA per year (i.e.6.0% per year) and a 0.5 percentage point reduction in employment (i.e. 3.0% per year) compared to the baseline projection, up to 2026.
- ‘Sector Downturn’ scenario: assumes sector underperforms compared to recent past and that policy interventions are unsuccessful in stimulating growth, resulting in a 2 percentage point reduction in growth in GVA per year (i.e.5.0% per year) and a 1 percentage point reduction in employment (i.e. 2.5% per year) compared to the baseline projection, up to 2026.

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[28] Rounded to nearest whole number

[29] Total number of jobs in sector is number of firms multiplied by exact FTE jobs per firm estimate for 2018 (38.2).

[30] We assume a greater impact on GVA growth than on employment growth due to gains in productivity.

Under these scenarios, estimates of Scottish Energy Efficiency sector GVA and jobs in 2026 are as follows:

Scenario	**GVA (2026)**	**Employment (2026)**
Business as Usual	£1.52 billion	10,815
Five Star Policy	£1.90 billion	12,134
Four Star Policy	£1.76 billion	11,680
Three Star Policy	£1.64 billion	11,240
Sector Slowdown	£1.41 billion	10,404
Sector Downturn	£1.31 billion	10,007

Table 22: Scenario GVA and employment projections

Under the ‘Five Star Policy’ scenario, the sector could generate an additional £380 million GVA per year and employ and an extra 1,319 jobs (FTE) than under the “Business as Usual” scenario. Under the ‘Five Star Policy’ scenario, sector GVA would be 114% greater than in 2018 and employment (FTE) would be 48% higher than in 2018, compared to a 72% increase in GVA and a 32% increase in employment (FTE) under the ‘Business as Usual’ scenario. On the flip side, under the ‘Sector Downturn’ scenario, the sector could generate £210 million less GVA per year and employ 808 fewer workers (FTE) than under the ‘Business as Usual’ scenario.

11 Conclusion and recommendations

Energy efficiency brings a wide range of benefits to households, businesses, society and the energy system as a whole. More efficient homes and buildings can help lower energy bills, improve health, comfort and well-being, and increase asset values for building owners. Improving energy efficiency is also one of the most cost-effective ways the UK has for meeting carbon budgets and can lead to greater efficiencies and cost-savings across the wider energy system.

Scottish Enterprise, in recognition of this growing local, national and international recognition of the significant commercial, economic and environmental benefits from increased energy efficiency, is developing a strategic approach which aims to maximise the associated economic benefit for Scotland. This study supports this aim by investigating Scottish capability and key emerging opportunities (related primarily to technologies and/or technological solutions), over the next ten years (i.e. circa 2018 to 2028), associated with the following three energy efficiency sub-sectors:

1. Efficiencies in building fabric and related technologies.
2. Efficiencies in domestic heat, including space and water heating.
3. Efficiencies at a network or aggregated community scale (excluding district heating), which may include elements of Energy Systems technologies.

The study draw the following conclusions and recommendations.

11.1 Conclusions

Policy Environment

There are favourable Scottish and UK policy (and growing EU and international) drivers for energy efficiency which offers growing potential for developers or suppliers of building fabric, space heating and/or aggregated energy efficiency technologies. The domestic drivers include, most notably:

- The Scottish Government’s ambitious targets for environmental performance (including significant heat demand reduction) as outlined in their Climate Change Plan (RPP3).
- The Energy Efficient Scotland: Route Map, which sets out different ways of improving both domestic and non-domestic properties up to 2040 and by this date it is expected that all dwellings will achieve an EPC band C as a minimum.
- The UK Government’s recent ‘Energy Company Obligation (ECO3)’ consultation, which sets out the policy of the scheme that will run from autumn 2018 until March 2022 initially (with confirmation UK Government funding of the same level as ECO will continue to at least 2028), to deliver energy efficiency and heating upgrade measures to homes in Great Britain (including Scotland). ECO has also became a devolved issue since 2016 and thus the Scottish Government has the ability to adapt the ECO targets accordingly within the same funding horizon (i.e. to 2028).
- Scotland’s Energy Efficiency Programme (SEEP). The cornerstone of Scottish Government’s National Infrastructure Priority on building energy efficiency, SEEP will combine existing energy efficiency and community energy programmes with devolved powers over Supplier Obligations. SEEP pilots are underway in 2018/19, thereafter a development phase to 2022/23 will see implementation of advice and support services, an assessment and consumer protection framework. Thereafter will be a full-scale operation of SEEP, facilitated by new regulation as deemed appropriate.

Internationally, the building sector is not on track to achieve global climate commitments however progress is being made with global initiatives, policies and technologies. Highly efficient building envelopes can help enable more efficient use of renewable energy and higher efficiencies in equipment (e.g. it can increase the efficiency of heat pumps due to lower temperature demands), as well as enable the use of additional energy sources (such as low temperature waste heat). Policy drivers such as building codes are creating market confidence in several parts of the world for new buildings that are energy-efficient. This creates potential opportunities for companies with relevant products and services.

The environmental challenges (and opportunities) that policymakers are trying to address are very complicated and the solutions are not straightforward. Policymakers face a further challenge that a range of solutions have been tried previously, with varying degrees of success due to a range of issues, and this has made some consumers and businesses sceptical about refurbishment schemes.

Emerging Opportunities

Whilst many barriers exist, the study has identified the following areas as those most likely offering emerging opportunities (in the UK, Europe and beyond) in the period between now and 2028.

Building fabric and related technologies

1) Factory manufactured / off-site constructed fabric elements or systems

With surveying tools providing more accurate measurement of existing dwellings it makes it is becoming increasingly easier to produce insulation products/panelling that can be manufactured off-site, to high levels of tolerance, for rapid installation on site as either an external or internal wall insulation product. Reducing site fixing/altering of products not only saves time on site / cost but can also lead to much improved installation and increased performance of the installed products.

2) New, high-performing, insulation products

Products that include newer emerging insulation technologies such as aerogel blankets/boards and Vacuum Insulated Panels (VIPs) could provide significant improvements in reducing heat loss. These thin solutions by their very nature are less disruptive to install to any thermal element than current traditional insulation materials.

3) New / improved insulation retrofit techniques

This category includes technologies and solutions that reduce impact on occupants, improve quality/consistency, reduce time and cost, etc. Treatment of ‘hard to treat’ properties have already led to new installation techniques being developed, or introduced. With these new or improved techniques it will be possible to return to previously upgraded properties to carry out further thermal improvements to elements previously disregarded for improvement.

4) Circular economy / embodied energy of building fabric components

There is an increasing focus on green / sustainable building products and especially those that offer future re-use / recycle-ability of building components. Making more use use/re-use of existing materials in new and innovative ways will need to play an increasingly significant role in reducing future carbon emissions as part of a circular economy.

Domestic space heating (and hot water) technologies

1) Heat Pumps (including high temperature heat pumps, hybrid heat pumps and gas driven heat pumps)

Emerging heat pump technologies such as high temperature, hybrid and gas driven heat pumps are likely to offer growth significant potential in the UK (and Europe and beyond) in the short to medium term.

2) Other low carbon heat technologies

Other low carbon heat technologies (e.g. solar thermal, biomass, traditional heat pumps CHP technologies, etc.) are also likely to need to play an important role in decarbonising the domestic heat markets over the next 10 years and beyond. This is especially true in the short to medium term (e.g. until such time as the above emerging heat pump technologies can mature and reduce in cost) and for rural / off-gas grid properties, as a significant barrier to wider roll-out remains the relatively low cost of gas boiler and gas fuels for areas on or near to the gas network. Hybrid heating systems could however play an increasing role for on-gas grid properties.

3) 'Smart' heating controls / heat storage / demand response technologies

Hybrid heating, energy storage (including storage heaters) and smart controls are also key facilitating technologies for 'aggregated solutions' as discussed below.

Aggregated energy efficiency solutions

1) 'Connected / smart' technologies and associated systems (including smart meters and appliances, digitalisation, data analytics, software development, local energy trading, etc.)

With the roll out of smart meters in every home in the 2020s, the domestic market for flexible demand could be significant and this is likely to present a significant opportunity for UK businesses. However, without tackling regulatory and cultural barriers, it is unlikely that the full benefits offered by demand flexibility will be achieved. Scotland has significant expertise in data analytics and software development and this could be used to help manage energy demand seamlessly and showing what can be achieved can enable these capabilities to be marketed to the world.

2) Built environment related 'flexibility' solutions (including Demand Side Response)

There are expected to many emerging opportunities in this area which could, for example, range from demand side response (DSR) of single and/or multiple energy vectors (e.g. electricity, heat and/or transport). Similarly, solutions could focus on single technologies but across large numbers of properties (e.g. aggregated DSR via smart appliances or energy stores) or consider multiple DSR opportunities (e.g. heating, electricity and storage) in individual buildings or across building stocks. There are growing opportunities in the systems and controls that can deliver these solutions.

It should also be noted that the return on investment for many emerging technologies can be relatively and so it can be difficult to make the case to consumers and businesses that they should invest in technologies that can take such a long time to payback. E.g. when considering heat pumps are generally cost effective in the long term, but tend to be expensive to install relative to a gas boiler. Radical solutions may therefore be needed to incentivise / fund energy efficiency refurbishments and/or make legally binding standards.

Geographical Market Opportunities

Energy Efficient Building Materials

Global investment in energy efficiency increased by 9% to $231bn in 2016, maintaining the upward trend of recent years. The rate of growth was strongest in China at 24%, though Europe is still responsible for the largest share of global investment (30% of the total). Among end-use sectors, buildings still dominate energy efficiency investment, accounting for 58% of the world total in 2016, with most investment in that sector going to building envelopes, appliances and lighting.

The global "green building materials" market size is expected to reach $364.6bn by 2022.[31] Growing demand for environmental-friendly and sustainable building materials is expected to propel the growth of the market. Technological innovations have facilitated a rise in demand in green building materials, as products are becoming increasing affordable and readily available. Increasing demand for green building materials coupled particularly in emerging economies is expected to have a positive impact towards market growth. In addition, presence of large number of manufacturers is expected to increase the ease in sourcing the products. Oversupply of green building materials is expected to lower product price which is expected drive the market growth over the forecast period. The market exhibits the presence of a large number of manufacturers engaged in the manufacturing of wide range of products including roofing, insulation, and frames. Easy accessibility to raw materials coupled with product demand is likely to increase industry rivalry which is expected to improve product quality.

Heating

The global space heating equipment market was worth $28.85bn in 2015 and is expected to witness considerable growth owing to the growing preference for energy efficient solutions.[32] Rapid industrialization coupled with increasing repair and renovation activities in the residential sector is projected to drive the demand for heating systems over the coming years.

One of the major trends influencing the heating equipment market is demand for products that are certified as energy efficient. Growing energy consumption in the industrial and residential sector is projected to drive the demand for solutions that decrease operation cost and enhance energy savings. The heating equipment industry is highly competitive, and companies are at the risk of losing business owing to several factors including price, technology, product performance, geographic presence, and customer service. District heating solutions are expected to gain prominence over the coming years.

Heat pumps accounted for 42.7% of the global revenue in 2015. Heat pumps are projected to grow rapidly on account of low operating cost and high operating capacity. Furnaces are the most common heating system used in the residential sector across the world. The demand for furnaces is anticipated to grow rapidly on account of its quick warming capability, easy availability of replacement part, and energy efficiency.

Europe is projected to experience high demand for energy-efficient and certified products. Favorable government policies related to reducing energy consumption are expected to boost the preference for technologically upgraded products and solutions. Demand from the Asia-Pacific region is projected to grow at the fastest rate in the medium term. Rapid industrialization and increasing R&D efforts to develop energy-efficient solutions is anticipated to lead to an acceleration in growth in demand over the coming years.

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[31] Grand View Research (2018).

[32] Grand View Research (2016).

Network or Aggregated Energy Efficiency

While individual clean energy technologies are the building blocks to clean energy transitions, a variety of “energy integration” technologies – such as smart grids, energy storage, and hydrogen, will play an increasingly important role to maximise the collective impact of individual technologies. Some areas are seeing signs of progress, but overall, these increasingly crucial integration technologies need more innovation and policy focus.

Investment in smart grid technologies grew by 12% between 2014 and 2016 overall, but key areas such as smart distribution networks are lagging behind, with investment growing by only 3% in 2017. Progress in smart meter deployment is uneven across countries, with further regulatory change and new business models needed for smart grids to play their critical integration role in clean energy transitions.

Globally, the theoretical potential of demand-side response is nearly 4,000 TWh per year, or more than 15% of total electricity demand. In the central scenario of the World Energy Outlook 2017, annual demand-side response potential is expected to increase to almost 7,000 TWh by 2040, the buildings sector leads future growth as demand for appliances and electric heating and cooling expands in Asia and Africa. Within developed economies, the electrification of heating and transport are major drivers of future growth. Smart charging of electric vehicles (EVs) uses charging (and discharging) of EV batteries to facilitate balancing of the power grid.

Mapping and company analysis

215 Scottish based companies have been identified as having ‘general’ energy efficiency capability or expertise. The table below shows the 215 companies by (i) business activity categories and (ii) sub-sector. There are a relatively small numbers of product manufacturers / developers with the vast majority of companies being service providers.

	Active/Potential	**% by sector**
Category	**(nr)**	**(%)**
product - manufacturer/developer	43	18%
product - supplier/distributor	14	6%
service provider	176	74%
research	4	2%
	237	(NB: some un-assigned/unclear)

Table 23: Analysis by business category

	Active/Potential	**% by sector**
Sub-sectors	**(nr)**	**(%)**
building fabric	25	20%
heating/hot water	92	72%
aggregated energy	10	8%
	127	(NB: some un-assigned/unclear)

Table 24: Analysis by sub-sectors

A subsequent mapping of the listed companies (Section 9.2) against the key emerging opportunity areas presented the following results:

Ref:	Nr of companies
-	0
🟥	1-5
🟧	6-10
🟩	>10

Table 25: Legend for the ‘Mapping of capability/potential in identified ‘key emerging areas’

Active	Potential?	Combined		
				Building fabric and related technologies
🟧	🟥	🟩	F1	Factory manufactured / off-site elements or systems
🟥	-	🟥	F2	New, high-performing, insulation products
🟥	-	🟥	F3	New/improved insulation retrofit techniques
🟥	-	🟥	F4	Circular economy / embodied energy of fabric components
				Domestic space heating (and hot water) technologies
🟥	-	🟥	H1	Heat Pumps
🟥	🟥	🟧	H2	Other low carbon heat technologies
🟧	🟧	🟩	H3	‘smart’ heating controls / heat storage / demand response
				Network or aggregated energy efficiency solutions
🟥	-	🟥	A1	‘Connected / smart’ technologies and associated systems
🟧	-	🟧	A2	Built environment related ‘flexibility’ solutions

Table 26: Mapping of capability/potential in identified ‘key emerging areas’

The following should also be noted when interpreting the results:

- The analysis focussed on the companies listed in the database developed via the project (as outlined above. As a results it is not exhaustive and as a result it may exclude other Scottish companies that are currently active and/or offering potential within the emerging areas.
- Companies identified as ‘potential?’ included companies within the database that have products, technologies, etc. that are related to the respective key emerging areas but typically present more ‘traditional’ systems or technologies (e.g. traditional hot water cylinder manufacturers, traditional timber frame manufacturing companies, or similar).
- This analysis includes a small number of non-Scotland based companies given that the parent database included some non-Scotland based companies. The colour rating of the ‘active’ companies within both ‘H3: smart heating controls / storage / demand response’ and ‘A2: built environment related flexibility solutions’ categories are most significantly influenced (circa 50%) by the non-Scottish company content.

The analysis highlighted the following:

- Scottish capability is generally low in all of the identified areas.
- There is a small number of additional companies (denoted 'potential?') whose technologies, products and/or systems may offer additional potential in the evolving areas.
- The highest level of current capability / 'clustering' is in areas F1, H3 and A2 and additional potential appears to be relatively high in areas H2 and H3.

The database of companies, and analysis, has been provided to Scottish Enterprise in Excel spreadsheet format.

Business and stakeholder consultations

Opportunities

Most firms that took part in the consultations were confident about both future growth in turnover and employment. Key geographical growth markets identified were: Scotland and the rest of the UK, EU, North America, India, China, Japan and Australia. Key product/services markets identified by consultees were:

- Building simulation
- Solar thermal water and space heating
- Supply to the new build and the social housing sector
- Manufacture of bespoke modular frames
- Building energy management
- Lighting & heating control
- Wellbeing management
- Internal wall insulation systems
- Fuel cell generators
- Phase change material based heat energy storage products
- Sewer waste water heat recovery systems and integrated design support
- Battery storage

Barriers

A range of common challenges that could constrain growth were identified by business. The most commonly referenced challenge was political uncertainty (relating in the UK to Brexit, but also including global geopolitical issues), whilst industry/product standards/regulation (which will vary from country to country) were the other main policy-related challenge. Market conditions, distance from growth markets were the main market-related challenges, whilst difficulties accessing finance to support growth reflects difficulties in securing funding from both private sector and public-sector sources. Concerns about competition may reflects concerns about cheaper imports and expansion by companies in other areas of the UK and internationally. Accessing suitable finance is a common challenge cited across most sectors of the economic as well as in the energy efficiency sector.

Intense competition is a double-edged sword, as on the one hand firms may face a potential loss of market share that companies, but on the other hand this competition should spur innovation and stimulate Scottish firms to move into higher value-added markets. Here, it is recommended that the Scottish Enterprise policy response should be to ensure that companies have access to targeted finance, procurement and international trade opportunities that can provide growth, have the right skills to exploit them (leadership & management, as well as technical skills) and the innovation and research capabilities to develop new products/services that enables them to compete on the global stage, which may necessitate closer collaboration and knowledge exchange between Scottish firms and the knowledge base (i.e. universities and other research institutions).

Future Support Needs

A wide range of business support requirements were identified by respondents. The most commonly cited requirements were related to developing collaborative partnerships (with other businesses and research institutions), which in part reflects the strong desire already mentioned among many firms to seek and exploit overseas collaborative opportunities, but also perhaps a lack of awareness of how to develop the necessary partnerships.

The most commonly cited business support requirements were:

- Developing collaborative partnerships with other businesses – this is likely to be most effective when collaboration is between businesses with complementary products and services or access to target markets (geographic or customer)
- Developing collaborative partnerships and agreements with research institutions – linked to the above, where access to research expertise can help to develop new products/services/processes
- Funding for projects – this is important for those companies who are themselves reliant on customers getting funding to implement energy efficiency measures
- General business financing – this is likely to be vital at every stage of a company's development
- Innovation and R&D – open innovation and supply chain programmes could help to stimulate greater investment in innovation and R&D
- Awareness of overseas energy policies and standards – this can help to reduce costs of researching and breaking into overseas markets
- Marketing information and/or advice – understanding how to segment customer markets and target them with the most appropriate message.

11.2 Recommendations

A number of recommendations are set out below. The first set of recommendations have been informed by insights gained during the study and a workshop with members of the Scottish Enterprise's construction and energy and low carbon teams. A number of additional recommendations, informed by feedback from businesses during the consultation phase of the project, are also presented.

Recommendations focussed on sector opportunities and Scottish capability

It is recommended that Scottish Enterprise consider adopting the following approach to build positively upon the findings of this study and to support relevant Scottish companies, and buyers, to maximise the benefits emerging from the opportunities and markets.

1. **Host Strategic Workshops and develop an Action Plan**

It is recommended that focussed workshops (facilitated by an independent party and consisting of one workshop for each of the 3 x sub-sectors) be progressed. The sessions should include key Scottish 'suppliers', 'buyers' and relevant other industry stakeholders. The 'suppliers' should include the companies who have been highlighted via this study as offering existing capacity or future potential in the key emerging areas. The 'buyers' should include a mixture of public and private building estate owners. It should also include Scottish Enterprise and Scottish Government policy-makers and procurement specialists to help address barriers and consider incentives.

The workshops should be designed to identify and develop key growth opportunities linked to existing or potential, near-future, Scottish capability. It should look to explore synergies between suppliers, buyers, the emerging opportunities. The workshop could also be used to review the 'current state of the market/technologies and highlight barriers and potential solutions. Whilst the focus for discussion should be flexible and open to be steered by the participants, topics to instigate initial creative thinking could include:

- Investigating key opportunities for substituting imported content? E.g. could imported content within developer / construction company supply chains be replaced with Scottish manufactured content? Also, rather than simply focussing on construction products that are currently manufactured in Scotland, a focus could also be considering what could viably be produced in Scotland that would provide significant impact, and what would it take to enable this?
- Investigating opportunities for reducing emissions associated with domestic heat e.g. by exploring the barriers associated with low carbon domestic heat technologies and identifying possible solutions and opportunities within a Scottish context.
- Investigating opportunities for developing aggregated energy solutions e.g. potentially involving and integrating expertise associated with power networks, controls, energy systems and/or innovative solutions that link with (predominantly non-built-environment) Scottish expertise in data, sensors and/or information and computer technology (ICT).
- Investigating general barriers (e.g. procurement, finance, reliable trial data, etc.) and identifying solutions.
- Investigating opportunities for Building Regulations (or other developing policies and regulations e.g. Local Heat and Energy Efficiency Strategies) (if relevant) to drive key strategic opportunities.

A key deliverable from the workshop should be the development of an Action Plan to maximise the economic potential for Scotland.

Scottish Enterprise may wish to consider establishing a working group with the aim of steering and driving forward the Action Plan and the linked activities suggested below.

2. Provide focussed ‘Expert Support’

The learning from the workshop (and the consultation feedback gathered within this study) should then be used to help shape an energy efficiency supply chain ‘export support’ service to provide specialist support to suppliers and buyers with solutions or technologies that align with the Action Plan aims.

3. Link outputs with strategic policy, industry and / or research initiatives

In order to maximise efficiency and impact, the Action Plan and Expert Support should link, where possible with existing (or planned) initiatives such as other relevant Scottish Enterprise business support, Scottish Energy Efficiency Programme pilots, Retrofit Scotland, Innovation Centre research initiatives, etc.

4. Test, trial, demonstrate, monitor and evaluate emerging solutions and support formal validation / certification of performance

It is recommended that the ‘expert support’ extends to the testing, trialling, monitoring and/or evaluation of solutions in order to robustly evaluate their effectiveness and reliability as independent evaluation of this nature adds value to product development and supports building buyer / consumer trust. It is also recommended that consideration be given to extending support to innovative or emerging technology providers to aid progression of independent third party validation and/or certification of their products as this is a critical barrier to exploitation and requirements can vary significantly by product and/or geographical market.

5. Develop an online Directory of Companies / Dissemination Platform

It is recommended that a directory of companies is created which can list, and promote, companies and their capability. The platform should aim to become a central focus point for the energy efficiency sector as well as for Scottish Enterprise, Scottish Government and Scottish Development International when promoting Scottish based expertise. It should showcase the sector whilst also assisting with wider dissemination and education by promoting Scottish Enterprise and/or sector-related activities, experience, current opportunities, etc.

The platform should also signpost to existing and established activities, groups, networks and sources of exemplar case studies (e.g. Innovation Centres, Retrofit Scotland, Constructing Excellence, BRE Innovation Parks, or similar). Furthermore, real-life demonstrators (developed via design competitions or similar) could also be developed as a means of showcasing what the sector can achieve. This could also provide a central point for research, commercialisation and consumer education related activity, whilst also acting as an important hands-on learning environment to support the education and skilling-up of industry practitioners, policymakers and consumers.

BRE would be happy to discuss and explore the above concepts with Scottish Enterprise and/or assist Scottish Enterprise in delivering such a process to assist Scottish businesses.

Additional recommendations informed by consultation feedback

The following recommendations are made based on the feedback of the telephone interviews and survey results and analysis, which highlighted specific business support needs relating to: collaborating with other businesses; networking; business finance; international support (predominantly in relation to standards and regulations, and to a lesser extent to trade); and innovation/R&D support.

Scottish Enterprise may wish to consider encompassing such support for firms in the energy efficiency sector with (existing and/or new) support schemes for the broader energy or low carbon sector, with common solutions delivered where appropriate and more tailored solutions delivered where there are specific needs identified.

6. Finance

There are numerous pathways to finance, not all of which are known to energy efficiency companies, and many of which are technology or market specific. It is difficult for companies to spend the time and resources accessing them and to know whether they are accessing the right options. Therefore a sector focused signposting and advisory service could serve as an important and valuable step to support companies to access suitable finance from the numerous sources already available.

Smaller companies that are developing new products often require relatively small amounts of finance to take these developments to the next stage and therefore a small scale finance fund or mechanism which is easy to access and, most importantly, fast to make a decision, would be beneficial here. It is often the speed of access rather than size that helps companies progress ahead of the competition. The sector in particular requires funding to support the commercialisation of new technologies, services and approaches.

A co-ordinated approach to developing funding packages for projects, especially for areas where initial pump priming is required to get the infrastructure in place which can then act as a framework for new and emerging technologies to be applied, may be beneficial.

7. Focused Support

Focused sector support enables sector and technology specific initiatives to be delivered efficiently and tends to be better appreciated by those companies that take advantage of the support available. It also enables a pool of knowledge and experience to be developed by the support organisations which will enable them to provide more effective support to sector companies.

a. International Trade Sector Focused Initiatives

As part of the sector focused initiatives there should be targeted export market support assistance including technology focused missions both outward and inward to the key export markets identified. A specific focus should be on making sure firms are aware of overseas energy policies and standards, which can help to reduce costs of researching and breaking into overseas markets. It is recommended that a small number of export markets for each sector are focused on and links developed with the various support organisations in those markets that can help Scottish companies develop their sales there. The trade initiative should provide Scottish companies with more opportunity to develop relationships in the selected markets and collaborate with overseas companies in the ways stated in the survey (i.e. joint ventures, technology licensing, technical co-operation – issues that have been raised as being important / needed by Scottish companies who are at an early stage in their export activities such as many in the sector appear to be, and which can often lead to a first step in developing international trade).

8. Innovation and R&D

Sector focused innovation groups have been proven in other areas of the UK to help companies develop products and services quicker and more effectively. Again the ability to develop relationships with academic and/or research organisations with a sector/technology/commercially-driven focus enables a real depth of understanding to be developed by the support organisation. This early view of the potential opportunities can be used by the companies to focus their innovation and research effort into specific technology/market areas, and by the sector support teams to assess where they should be focusing their support.

Through the use of sector and/or technology specific networks the links between Scottish companies, research establishments, academic institutions, testing and accreditation bodies and/or demonstration facilities should be strengthened. The sector focused support should identify technology calls for funding opportunities and support Scottish companies to access them when relevant and appropriate. This could include Knowledge Transfer Partnerships (KTPs) between firms

9. Training Support

The recruitment of staff with relevant technical skills is another vital area where local companies can be supported. E.g. supporting the development of centres with relevant training modules and qualifications would support local companies to develop existing staff and provide a pool of potential recruits. An issue highlighted in similar projects in Scotland and England was the need to develop links with school / college / university leavers to make them aware of the career possibilities available and support them to obtain energy efficiency sector jobs with local companies via careers advice and green jobs fairs.

Appendix A Policy Review

Scottish Government's Climate Change Plan

The Scottish Government have set new and ambitious targets for environmental performance as outlined in their Climate Change Plan (RPP3). In terms of building performance, the plan focuses on dramatic reductions in emissions from buildings, both residential and non-domestic, by 2032. This will be achieved through energy efficiency measures and the decarbonisation of heat, combined with the decarbonisation of electricity as far as possible, and a move towards the use of electricity to heat our homes.

The Climate Change Plan sets out a trajectory which requires:

- Reduction in domestic buildings' heat demand by 15% through improvements to the building fabric by 2032.
- Reduction in non-domestic buildings' heat demand by 20% through improvements to the building fabric by 2032.
- 11% of non-electrical heat demand to be from renewable sources by 2020.

Additional key statements within the Plan, that are appropriate to this study, include:

- The energy efficiency of Scotland's residential and non-residential buildings will ensure that we keep our homes, schools and businesses warm while conserving energy.
- Over the period of the Plan, we expect to see an overall reduction in emissions of 33% from Scotland's buildings.
- To achieve this, emissions from Scotland's residential and non-domestic buildings will need to fall by 23% and 53% respectively.
- Where technically feasible by 2020, 60% of walls will be insulated and 70% of lofts will have at least 200mm of insulation in the residential sector.
- Improvements to the building fabric of Scotland's buildings will result in a 15% reduction in residential and 20% in non-residential heat demand.
- Increases in the deployment of measures such as cavity wall, floor and loft insulation, secondary glazing, smart meters and programmable thermostats will provide consumers with opportunities for cost savings from reducing heat demand, help to alleviate fuel poverty and make businesses more competitive by releasing savings from fuel bills that can be invested in frontline services.
- Raising the energy efficiency of Scotland's building stock will help to minimise the impact of any fuel price rises in future.
- A growing market and supply chain for energy efficiency services and technologies will stimulate innovation and entrepreneurship, and ensure the people of Scotland live and work in warm buildings in both urban and rural areas.

Scottish Government's Energy Strategy: The future of energy in Scotland

Scotland's first Energy Strategy sets out the Scottish Government's vision for the future energy system in Scotland until 2050. It articulates six energy priorities for a whole-system approach that considers both the use and the supply of energy for heat, power and transport.

The Strategy will guide the decisions that the Scottish Government, working with partner organisations, needs to make over the coming decades, is built around the following six energy priorities:

- Promote consumer engagement and protect consumers from excessive costs;
- Improve the energy efficiency of Scotland's homes, buildings, industrial processes and manufacturing;
- Ensure homes and businesses can continue to depend on secure, resilient and flexible energy supplies;
- Empower communities by supporting innovative local energy systems and networks;
- Champion Scotland's renewable energy potential, creating new jobs and supply chain opportunities; and
- Continue to support investment and innovation across our oil and gas sector, including exploration, innovation, subsea engineering, decommissioning and carbon capture and storage.

There are a number of aspects noted within the strategy that relate to the energy efficiency sub-sectors of interest to the study, for example:

- Energy efficiency leading to reduced energy demand is a key ingredient.
- Enhanced energy efficiency and improved productivity will help curb energy consumption without limiting growth – enabling the continued reduction in emissions whilst still growing the Scottish economy
- We will need to collaborate across public, community and private sectors – building upon our existing partnership approach with local government and other organisations, trade bodies and community groups. This will help to manage any tensions and trade-offs, and maximise the beneficial outcomes for Scotland.
- By 2050, SEEP will have transformed the energy efficiency and heating of Scotland's buildings. This will make our homes, shops, offices, schools and hospitals warmer and easier to heat.
- Reducing energy demand will help tackle fuel poverty, help businesses become more competitive, and release savings in the public sector for front line services.
- SEEP offers a huge opportunity for construction and energy systems technologies companies, with low carbon building technology sales in Scotland forecast to be worth £1.9 billion by 2020.

Energy Efficient Scotland: Route map

The Route Map for the Energy Efficient Scotland programme sets out the journey Scotland's homes, businesses and public buildings will take to become more energy efficient. It serves to guide the decisions that Scottish Government will be making over the next 20 years to improve the energy efficiency of Scotland's buildings and decarbonise their heat supply. The route map identifies that this will be achieved by setting energy efficiency standards for our domestic and non-domestic buildings and being clear on how and when these will be achieved.

The Energy Efficient Scotland Programme's focus is on improving the energy efficiency of existing buildings, it will not extend to new buildings. Energy Efficient Scotland delivers across two key policy areas of Government: fuel poverty and climate change. Because of this it has two main objectives:

- Removing poor energy efficiency as a driver for fuel poverty.
- Reducing greenhouse gas emissions through more energy efficient buildings and decarbonising our heat supply.

Given the scale of the Scottish Government's ambition to eradicate fuel poverty, mitigate climate change, and grow the Scottish economy in an inclusive way, energy efficiency has been designated as a national infrastructure priority by Scottish Ministers.

The route map proposes clear long term energy efficiency standards that buildings will need to achieve by 2040, and hence it is crucial to understand how fabric technology readiness between now and 2025/35 fits into this long term aim. It also sets out the pathways that different building sectors will take between now and then to achieve or exceed that standard. The route map is not set in stone, but offers suggested initial steps as well as the long term (i.e. 2040) goals.

The Programme will run for 20 years and will involve activities as varied as improving the energy efficiency of the majority of buildings, decarbonising the heat supply to off-gas grid properties and supporting the development of district heating networks (e.g. via the proposed introduction of a statutory duty on local authorities to develop LHEES (Local Heat and Energy Efficiency Strategies).

Until the mid-2020s, the Programme will focus on improving the energy efficiency of Scotland's existing buildings, as well as continuing to support the deployment of low regrets, low carbon heat options (such as individual renewable heat technologies for those buildings not connected to the gas grid or heat networks where they make sense). The future shape of the gas and electricity networks will impact on Energy Efficient Scotland and our approach to decarbonising heat. It is important the Programme can adapt to any changes, including network changes. In the mid-2020s, there will be the first of a series of Programme reviews.

Key statistics and considerations include:

- Households, businesses and public services across Scotland spend around £2.5 billion every year on heating and cooling the buildings we use each day. This represents the largest part of Scotland's energy use (over 50%) and is therefore crucial to the Scottish Energy Strategy and Climate Change Plan.
- Many of Scotland's buildings are inefficient and hard to heat which increases energy bills and wastes money. This leads to fuel poverty, puts pressure on household finances, and can have adverse effects on people's health. Similarly, for many of Scotland's businesses and public services, energy inefficiency and high energy bills adds unnecessary financial burdens and has the potential to hold back economic growth.
- For dwellings (new and existing) this long term goal is that all dwellings by 2040 will achieve EPC band C as a minimum, where this is not technically feasible or cost effective those dwellings should still be improved as far as possible. All new built dwellings achieve at least an EPC band C now. Achieving an EPC band C does require that existing dwellings would need to undergo significant levels of fabric improvements. There are a range of intermediate steps suggested across different tenures however;
    - For owner occupiers it is suggested that;
        - Improving the dwelling to EPC band C should be encouraged up to 2030
        - But potentially mandatory after 2030.
    - Private rented;
        - From 1 April 2020, EPC band E at change in tenancy, all EPC band E by end March 2022.
        - From 1 April 2022, EPC band D at change in tenancy, all EPC D by end March 2025.
        - Proposing EPC band C by 2030.
    - Socially rented (90% of which are already achieving an EPC band D or above);
        - Maximise the number of socially rented homes achieving EPC band B by 2032.
        - Long term vision to 2040, for all social housing to be carbon neutral as far as reasonably practical.
    - Households in fuel poverty;
        - All homes to achieve EPC band C by 2030.
        - All homes to achieve EPC band B by 2040.

- For those properties to be improved to achieve EPC band B would be a combination of significant levels of fabric improvements as well as installation of low carbon technologies.
- Non-domestic buildings to be covered by a consultation on improving energy efficiency ahead of any local plans.

Space heating related extracts include:

- Heating our homes and the water we use accounts for over three-quarters of the energy we use in our homes. The majority of households use mains gas for their heating, with smaller proportions using electricity and oil as their main fuel source.
- Around 8 out of 10 Scottish dwellings use gas as primary heating fuel.
- Heat decarbonisation approaches where relevant, e.g. renewable heat in off-gas areas and district heating where appropriate.

Scotland’s Energy Efficiency Programme (SEEP)

SEEP is the cornerstone of Scottish Government’s National Infrastructure Priority on building energy efficiency. It will combine existing energy efficiency and community energy programmes with new devolved powers over Supplier Obligations on energy efficiency and fuel poverty. A SEEP pilot phase is underway with projects running to 2018/19. Thereafter a development phase to 2022/23 will see implementation of advice and support services, an assessment and consumer protection framework. Thereafter will be a full-scale operation of SEEP, facilitated by new regulation as appropriate. The Scottish Government’s vision is a scheme which combines and consolidates interventions across all of Scotland’s building stock –domestic (social and private), public, commercial and industrial – making use of delivery mechanisms shown to work and deliver value for money.

SEEP is a major programme aimed at delivering millions of pounds in energy savings, support and creation of jobs across Scotland, delivering a substantial Scottish market and supply chain for energy efficiency and renewable heat services and other technologies and related expertise which is transferable to international markets. However, this will happen only if the appropriate technologies are available and market ready and if a support plan and associated work streams are put in place.

In 2017 ClimateXChange commissioned three SEEP technology landscaping studies to identify near to market technologies that had the potential to contribute to delivering the SEEP objectives. A summary of this research is provided later.

UK Clean Growth Strategy

Affordable energy and clean growth are central objectives of the UK’s Industrial Strategy. Improving how productively we use energy, through improved energy efficiency is an important component of how we meet those objectives.

The UK Government is determined to bring down the costs of energy for all consumers, including by delivering on the aspiration set out in the Clean Growth Strategy for as many homes as possible to reach EPC Band C by 2035 where practical, cost effective and affordable.

The Clean Growth Strategy announced that the Government would extend support for home energy efficiency to at least 2028 at the current level of ECO funding.

Energy Company Obligation (ECO3) 2018 to 2022 – Consultation (2018)

The UK Government's response to the Energy Company Obligation (ECO3) consultation sets out the policy of the scheme that will run from autumn 2018 until March 2022. The scheme delivers energy efficiency and heating measures to homes in Great Britain (including Scotland). UK Government are proposing to focus the whole scheme on Affordable Warmth such that low income and vulnerable households are the beneficiaries of measures installed under the scheme; consequently the Carbon Emissions Reduction Obligation (CERO) will be removed

The scheme's main policies include:

- Focusing the ECO scheme to support low income, vulnerable and fuel poor households who are least able to adequately heat their homes and most likely to suffer from these impacts.
- Reducing the current supplier obligation threshold of 250,000 customer accounts (or equivalent) for the scheme, in a phased way, to 150,000 customer accounts (or equivalent) from 2020
- Requiring 15% of measures to be delivered to rural homes
- Increasing the proportion of the scheme that can be delivered under local authority flexible eligibility to 25%
- Allowing up to 10% of a suppliers' obligation to be met through the delivery of new, innovative products
- Supporting households that have a broken heating system by allowing the equivalent of 35,000 broken heating systems to be replaced per year
- Encouraging a multiple measure approach by allowing the replacement of inefficient heating systems to be replaced (outside of the broken heating system cap) if they are installed alongside insulation
- In order to support the supply chain and encourage innovation in an area where it is most needed, the UK Government are proposing to introduce a target to improve the equivalent of 17,000 solid walled homes per year, either through solid wall insulation, or using a combination of other technologies (if equivalent savings can be achieved in the property). The consultation highlights that there are an estimated 8.5 million homes of solid wall construction in Great Britain but less than 10% of these currently have solid wall insulation.

The changes are an important step on the road to meeting UK Government commitment to improve the energy efficiency rating of fuel poor homes to EPC Band C by 2030. In order to ensure high standards of installation quality and customer service, the UK Government intend to adopt the changes of the 'Each Home Counts'[33] independent review of consumer advice, protection, standards and enforcement for energy efficiency and renewable energy (December 2016), under ECO. A central recommendation of the review was the introduction of a quality mark that will aim to improve installation quality and customer service. Other key considerations include:

- UK Government are proposing to make it easier to install First Time Central Heating (FTCH), so that homes with broken or inefficient electric storage heaters can be eligible for FTCH.
- Proposals that suppliers can choose to meet up to between 10% and 20% of their obligation through innovative measures. This is intended to encourage products and methods of installation which are ready for market but not currently eligible under ECO or delivered in large volumes.
- There is recognition that renewable heat technologies have a big role to play in decarbonisation of domestic heating. However, to maintain value for money and avoid double subsidy the

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[33] https://www.gov.uk/government/publications/each-home-counts-review-of-consumer-advice-protection-standards-and-enforcement-for-energy-efficiency-and-renewable-energy

Government are proposing that measures which receive support under the Renewable Heat Incentive will not be eligible under ECO.

- The UK Government propose to limit eligible primary insulation measures to:
    - flat roof insulation;
    - loft insulation;
    - rafter insulation;
    - room-in-roof insulation;
    - wall insulation (insulation of a cavity wall or solid wall insulation);
    - insulation of a mobile home; and
    - under floor insulation

Scottish ECO considerations

The Scotland Act 2016 provides Scottish Ministers with powers to design and implement ECO in Scotland, including setting rules about the types of households and measures eligible. Should Scottish Ministers decide to use their powers during the period of ECO3, the UK Government propose to apportion lifetime bill savings targets based on gas and electricity supply volumes in Scotland and the rest of Great Britain. The UK Government would also work closely with the Scottish Government to ensure that the design of both schemes was consistent with the overall funding envelope and objectives. If Scottish Ministers decide to make separate rules or sub-targets for ECO in Scotland and the Affordable Warmth target for ECO3 is apportioned between Scotland and the rest of GB, the UK Government would propose to reduce the solid wall sub-target to approximately 12,000 homes per annum in England and Wales to account for the loss of installations in Scotland.

A Comparative Review of Housing Energy Efficiency Interventions (2015)

Regarding funding mechanisms in general, the above, which included a review of a selection of policies from similar countries and large States in America, determined that it is not necessarily the mechanism itself that is the main focus of customers, but rather that the long-term stability of interventions is important and schemes that work well, and at scale, are usually supported by high levels of public subsidy. A staged approach when implementing a new programme prevents substantial policy failure as good evaluations can help to understand a programme's impact and identify potential modifications where needed. Also crucially, all interventions have an impact on a wide range of issues and contribute to multiple policy goals. Assessing those multiple benefits of energy efficiency and linking them explicitly to other areas helps to develop an integrated approach rather than policy silos. Additionally trust is crucial for the successful delivery of a programme.

Appendix B Geographical Market Analysis

This section researched current international trends in building sector energy efficiency.

International Trends in Energy Efficiency

The International Energy Agency (IEA) Tracking Clean Energy Progress report[34] provides a comprehensive and rigorous assessment of a full range of energy technologies and sectors that are critical in a global clean-energy transition. It includes the most up-to-date information for where technologies are today and where they need to be according to the IEA's Sustainable Development Scenario (a pathway to reach the Paris Agreement on tackling climate goal) to deliver universal energy access and significantly lower air pollution. The report covers five broad sectors: power; buildings; transport; industry; and energy integration.

The IEA's Sustainable Development Scenario (SDS) outlines an ambitious, yet achievable transformation of the energy sector. Meeting long-term sustainability goals requires a combination of more energy efficient buildings, industry and transport, and more renewables and flexibility in power.

In order to achieve the SDS targets by 2040 the IEA identifies decarbonising the power sector as a fundamental step to reducing emissions, complemented by efficiency improvements in buildings, in particular by addressing growing demand from cooling, heating and powered devices. The report also states that the transport sector will need to undergo a major transformation, including shifts from oil to electricity to reap the benefits of clean power generation. Industry processes that can't be easily electrified must cut emissions through efficiency, aggressive innovation and carbon capture. And energy integration technologies will become increasingly important as shares of variable renewables rise. The cumulative reductions required by each of the five sectors is shown below:

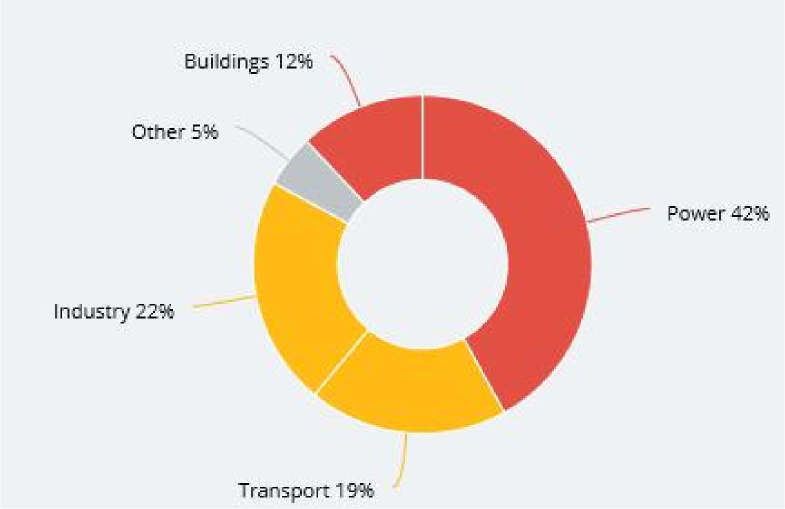

Figure: Energy Sector Emissions Reduction (Source: IEA) (Note: Cumulative reduction requirement in emissions from 2017 to 2030)

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[34] IEA (2018).

International Trends in Building Sector Energy Efficiency

General Trends

Energy efficiency in buildings continues to improve, thanks to policy action and technological advances. Policies have focused primarily on the building envelope, rather than heating and cooling equipment. There is considerable potential to achieve further energy savings by establishing or strengthening standards. Efficiency improvements of 10% to 20% are possible in most countries from appliances, equipment and lighting products that are already commercially available. There is strong global momentum towards more efficient lighting; by 2022, 90% of indoor lighting worldwide is expected to be provided by compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs).

Nevertheless, the buildings sector is not on track to achieve global climate commitments, but progress is being made with global initiatives, policies and technologies. Annual net building-related GHG emissions peaked at 9.5 gigatonnes (GtCO2-eq) in 2013 and decreased to 9.0 Gt in 2016. However, buildings final energy consumption grew steadily from 119 EJ in 2010 to 124 EJ in 2016 as a result of increasing floor area growth, which is outpacing energy intensity reduction

Progress on energy efficiency policies for buildings continues to increase, though the share of progress on building envelopes by country varies compared with progress on heating, ventilation and air conditioning (HVAC) equipment. In some countries, such as Denmark and Germany, building envelope policy has been the key driver for policy progress, while in other countries, such as Japan and Korea, HVAC equipment has been a key driver. A combination of both envelope and equipment policies is critical for the transition to sustainable buildings. Highly efficient building envelopes enable the use of higher-efficiency equipment and energy sources, such as low temperature waste heat, heat pumps and renewable energy.

Global investment in energy efficiency increased by 9% to $231bn in 2016, maintaining the upward trend of recent years. The rate of growth was strongest in China at 24%, though Europe is still responsible for the largest share of global investment (30% of the total). Among end-use sectors, buildings still dominate energy efficiency investment, accounting for 58% of the world total in 2016, with most investment in that sector going to building envelopes, appliances and lighting.

Energy Efficiency in Buildings Policy Drivers

Building codes are creating market confidence in several parts of the world for new buildings that are energy-efficient. Mexico took two major steps in the last year, including publishing the first national building energy efficiency code in collaboration with the International Code Council, and launching a building energy code roadmap that provides national targets in three-year increments to 2050. California is leading the way in the United States, with the latest 2016 Building Energy Efficiency Standards estimated to exceed the energy savings of the 2015 International Energy Conservation Code. In 2017, India released a much anticipated update to the Energy Conservation Building Code, a national model code that can be adopted and enforced by state and local governments to improve the efficiency of non-residential buildings.

Appliance, equipment and lighting standards can lead to additional energy savings in buildings. Last year, the IEA Energy Efficient End-Use Equipment Technology Collaboration Programme (IEA 4E-TCP) reported energy savings of 16% to 26% over the past 10 years for major household appliances. The programme has now identified that further efficiency improvements of 10-20% are available in most countries from products already being sold in the market, including energy savings of over 75% by switching from halogen lighting to LED lighting. IEA 4E-TCP estimates that the market for efficient lighting will continue to grow and that 90% of all indoor lighting will be efficient (CFLs and LEDs) by 2022, due to a combination of improved policy and decreasing cost of efficient lighting. In Chile, the refrigerator market has shifted from 15% energy efficiency label A or better in 2007 to nearly 90%, a case of policy success, but one that now requires a policy update to continue to shift the market to more efficient refrigerators (FCH, 2016).

Energy Efficiency in Buildings Technology Drivers

Meters and controls are connecting buildings with big data. The IEA Energy in Buildings and Communities Technology Collaboration Programme (IEA EBC-TCP) has initiated research projects to better understand how buildings use energy, including EBC Annex 70 Energy Epidemiology and EBC Annex 71 Building Energy Performance Assessment Based on In-situ Measurements (IEA EBC-TCP, 2017). These two projects are looking at how detailed building energy use data can be used to make policy and building operation decisions that increase efficiency. This approach is enabled by increasing digitalization and the ability to capture and analyse large data sets.

Increasing the efficiency of water heaters raises different issues for policy makers in different regions, due to variations in consumer hot water use, environmental conditions and energy infrastructure impact. More energy can be saved by switching between types of water heater than by increasing the efficiency of each equipment type; heat pumps enable energy savings of 60% to 85% compared with typical instantaneous and storage heaters. Japan's Top Runner programme and Australia's white certificate schemes have enabled the water heating markets in both countries to have increasing sales of highly efficient heat pumps, with over 500,000 heat pump water heaters sold in Japan alone each year (IEA 4E-TCP, 2017).

Heat pumps are increasingly being recognised as a solution for many building energy needs. For years, less sophisticated heat pumps did not efficiently operate in cold climates. New findings from the IEA Heat Pumping Technologies Technology Collaboration Programme (IEA HPT-TCP) Annex 41 show that cold climate heat pumps are being introduced to the market that can operate much more efficiently with a heating capacity output higher than 70% in temperatures of -25°C (IEA HPT-TCP, 2017). Cold climate heat pumps could shift significant portions of global heating energy use away from less efficient electric and fuel heating systems in mixed and cold climates. In district energy systems, large-scale heat pumps are improving the efficiency of space heating, water heating, cooling and refrigeration. Heat pumps are an increasingly cost-effective way to meet both energy efficiency targets and countries' emissions reductions targets. This is leading to new combined approaches to policy thinking, such as the EU heating and cooling strategy (European Commission, 2016b).

Energy Efficiency in Buildings is Key to Global Environmental Goals

Two key international agreements – the Paris climate change agreement and the Montreal Protocol on ozone depletion – are targeting energy efficiency in buildings as a means to achieve broader goals. The result could be a significant boost for energy efficiency efforts worldwide. The launch of the Global Alliance for Buildings and Construction (GABC) at the COP21 climate summit in 2015 and the Kigali Amendment to the Montreal Protocol in 2016 have motivated funders and other interested parties to support efforts to increase energy efficiency. Energy efficiency efforts are being added to the existing Montreal Protocol network due to the Kigali Amendment to reduce the use of ozone depleting hydrofluorocarbons for cooling, the fastest growing end-use in buildings.

The GABC has brought together 24 countries and 72 non-state organisations to work towards a global buildings and construction sector that is low-carbon, energy-efficient and resilient. GABC partners are supporting global efforts on awareness, education, policy, finance, data and market transformation. GABC is tracking global actions in the buildings sector, including the 88 buildings-related NDCs pledged under the Paris Agreement, as well as 3 000 city-level commitments and 500 private sector actions for the building sector that have been registered with the United Nations Framework Convention on Climate Change (GABC, 2017). Companies have increased their support for energy efficiency awareness, capacity building, financing models and policies through private initiatives like the Amplify initiative.

Companies Boost Energy Efficiency in Buildings through the Amplify Initiative

The World Business Council for Sustainable Development (WBCSD) leads the global Energy Efficiency in Buildings (EEB) Amplify initiative. This private sector-led initiative aims to achieve substantial reductions in building energy consumption globally. It brings together local building companies and city officials to develop a common understanding of market barriers and develop action plans to unlock investments in energy efficiency city-wide. The initiative sets up local platforms that act as catalysts for change in four main areas: (1) awareness of the benefits of energy efficiency (i.e. the business case); (2) the need for proper skills and collaboration throughout the value chain; (3) adequate financing models; (4) the need for consistent and long-term policy frameworks (i.e. regulations and incentives).

In 2017, EEB Amplify is being rolled out in Europe in partnership with the European Climate Knowledge and Innovation Community (Climate-KIC), with initial engagements in Switzerland (Zurich), the United Kingdom (Birmingham), Romania (Bucharest) and France (city to be confirmed); and in the United States in partnership with the U.S. Green Building Council (Phoenix and Brooklyn).

Emissions from Buildings

The IEA report found that the Building sector[35] was not on track to meet the SDS goals. Emissions from buildings appear to have peaked in 2013, although their energy consumption rebounded slightly in 2017 as the equivalent to the current floor area of Germany was added to the global building stock. Buildings, which were responsible for almost a third of final energy consumption last year, remain off track to meet the SDS target. The energy and emissions savings potential remains largely untapped because of continued use of less efficient technologies, lack of effective policies and weak investments in sustainable buildings.

Final energy use by buildings grew from 2,835 Mtoe in 2010 to nearly 3,000 Mtoe in 2017, while the share of fossil fuel use in buildings sector energy demand decreased slightly to around 36%. As a result, direct emissions from buildings stayed just under 2.9 GtCO2 per year as they had been since 2010.

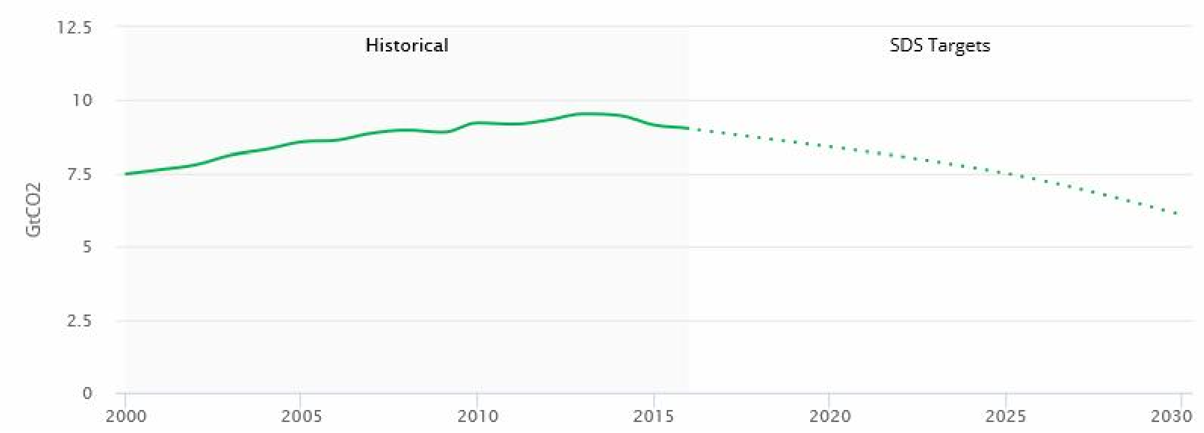

Figure 2: Emissions from Buildings (Source: IEA)

When indirect emissions due to energy use from upstream power generation are taken into account, buildings were responsible for 28% of global energy-related CO2 emissions in 2017, or 9.0 GtCO2.

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[35] The IEA identifies six building efficiency technologies: building envelopes; heating; cooling; lighting; appliances & equipment; and data centres & networks.

Global annual buildings-related carbon emissions appear to have peaked in 2013, at least temporarily, at a high of about 9.5 GtCO2. But the drop in recent years is largely due to progress in reducing the carbon intensity of power generation, rather than greater buildings efficiency.

Building Sector Energy Intensity

Buildings sector energy intensity continues to improve by 1.5% a year. Yet floor area has grown by as much as 2.8% a year since 2000, offsetting those energy intensity improvements. To reach SDS goals by 2030, the annual global rate of energy intensity improvement has to reach 1.9%. While the increase may seem marginal, it entails that the rate of change needs to double or more in some critical emerging markets, particularly in Africa, Latin America and Asia. A similar rate of change is needed in major developed economies, which need to step up significantly deep energy renovations of existing buildings.

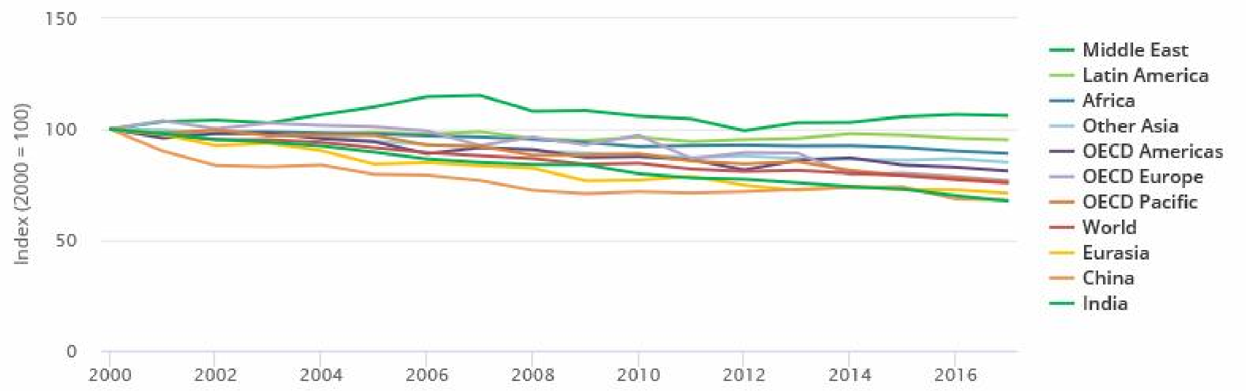

Figure 3: Building Energy Intensity Source: IEA) (Note: Change in buildings total final energy used per m2)

Though the sector continues to fall short of the SDS trajectory, the call to achieve a sustainable buildings sector is increasingly being heard. As of 2017, 132 countries have explicitly mentioned buildings in the nationally determined contributions (NDCs) they had submitted to the United Nations Framework Convention on Climate Change (UNFCCC). Of those, 101 countries pointed to energy-efficiency opportunities to meet emissions reduction targets, and 49 committed to using renewable sources of energy in buildings to improve access to clean energy and endorse adoption of low-carbon energy assets.

At the same time, the majority of NDCs mentioning buildings do not include specific projects or explicit targets related to energy performance standards or efficient building technology deployment. If NDC pledges are taken at face value, ambitions set forth would only cover 13% of global buildings sector CO2 emissions beyond what is already covered by existing policies.

Policy on Energy Consumption in Buildings

Energy efficiency policy progress in buildings continues to improve, with around 38% of buildings energy use covered by policies in 2017, up from 28% in 2010. Lighting has made the most impressive progress, with three-quarters of energy use now covered by energy-efficiency policies, thanks to a major push to phase out incandescent lamps over the last decade. An increasing number of countries have also added standards and labelling programmes for major appliances since 2010, although policy coverage for the end use remains at only 35%.

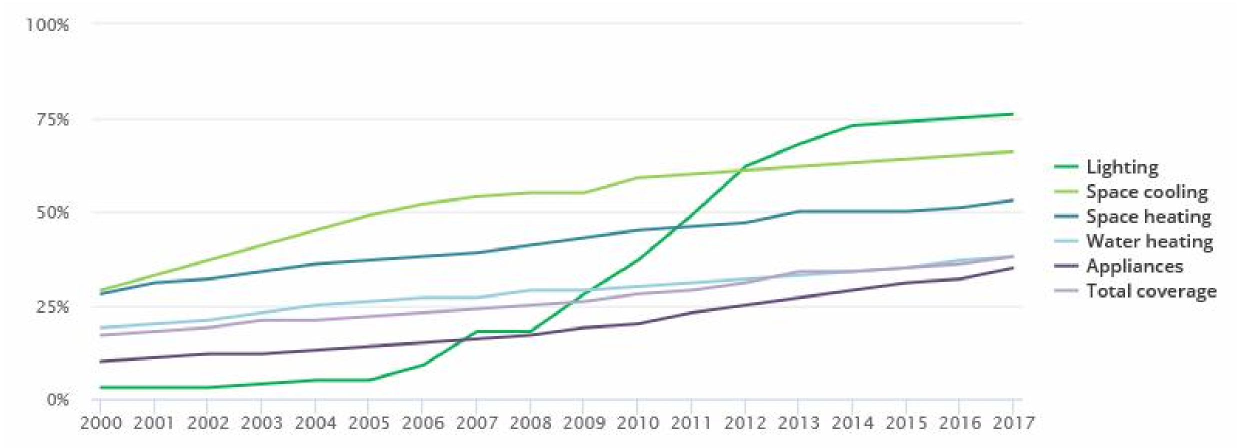

Figure: Building Energy Efficiency Policy Coverage (Source: IEA) (Note: % of energy use covered by energy-efficiency policies)

Despite the overall upward trend in buildings energy policy coverage, the annual rate of improvement has diminished, from 5-8% in the 2000s to 2-3% in recent years. Figures for policy coverage do not indicate how stringent polices are. Many policies have not been updated to increase stringency. For example, lighting policies in many countries have not been updated to phase-out halogen lamps.

Energy Efficiency Investments

In 2016, global investment in energy efficiency increased by 9% to $231bn. This increase coincided with a slowdown in investment on the supply side of the energy system. Energy efficiency investment now represents 13.6% of the $1.7trn invested across the entire energy market (IEA, 2017a).

China accounted for most of the investment growth in 2016, with a 24% increase from 2015. Investment increased by 10% in the European Union and decreased by 2% in the United States. This decrease was largely due to a decrease in investment in the United States transport sector. Lower international oil prices were especially pronounced in the United States, making the investment in fuel efficient vehicles less attractive (IEA, 2017a). At a sectoral level, transport accounted for 26% of incremental energy efficiency investment in 2016, industry 16% and buildings 58%.

Over the past three years, energy efficiency investment in the buildings sector increased steadily, growing by 8% in 2015 and 12% in 2016. Only a small share of the spending on new buildings is considered energy efficiency investment, as the majority is considered an autonomous improvement. However, three-quarters of spending on existing building energy efficiency retrofits was considered energy efficiency investment in 2016.

Incremental energy efficiency investment in buildings was $133bn in 2016, one-third of the $406bn in total energy efficiency spending on projects in the sector. Lighting had the highest incremental investment as a share of total energy efficiency spending, with just over 60%. In each of the other building sub-sectors, incremental investment is less than 40% of total energy efficiency spending.

Unsurprisingly, given the lack of major policy progress and clear market signals, investments for sustainable buildings are lacklustre. Total spending on energy-efficient products and services in buildings was around $550bn in 2017, amounting to 9% of the $4.9trn spent on buildings and construction, including renovations. Still, this represents an increase of 10% in energy efficiency investments in the buildings sector since 2016, suggesting that investor confidence in sustainable buildings may be growing.

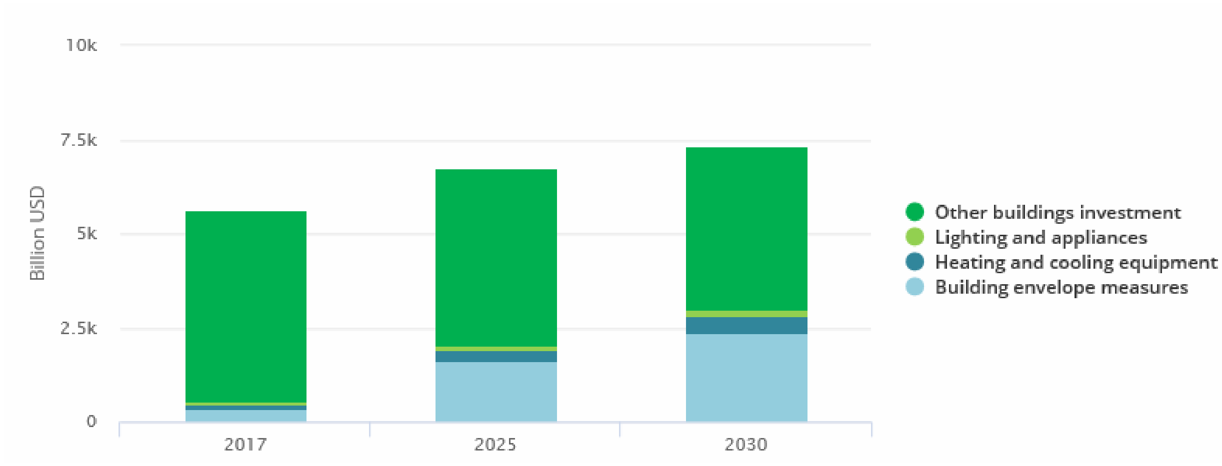

Figure 5: Building Energy Efficiency Investments (Source: IEA)

However, to meet the SDS goals by 2030, these investments need to rise drastically, and reach 40% of total buildings and construction spending. Building envelope measures – including near zero energy buildings construction and deep energy renovation of existing buildings – need to increase 3.5-fold by 2030.

Technology Progress

Here we provide summaries for each of the six main building technologies as categorised by the IEA, and provide greater detail on the two most relevant for this study: building envelopes; and heating.

- **Building envelopes**. Two-thirds of countries around the world lacked mandatory building energy codes in 2017, meaning that more than the current floor area in the US will be built using less efficient technologies over the coming decade. To meet the SDS target, the number of new high-efficiency buildings being built needs to increase from 75m m^2 today to more than 2bn m^2 by 2030. Deep energy renovation of existing stock also needs to more than double within the coming decade (with the current rate less than 1%).
- **Heating.** Sales of heat pumps and renewable heating equipment have continued to increase by around 5% per year since 2010, representing 10% of overall sales in 2017. Fossil-fuel equipment, however, still represents 50% of sales; less-efficient, conventional electric heating equipment represents another 25%. To meet the SDS target, the share of heat pumps, renewable heating and modern district heating needs to triple to reach more than one-third of new sales by 2030.
- **Cooling.** Energy demand for cooling is the fastest growing end-use in buildings, with sales rising three times faster than efficiency improvements. To put cooling on track to meet the SDS target, minimum energy performance standards need to push markets to improve AC performance by more than 50% by 2030.
- **Lighting.** 2016 and 2017 were a critical turning point for energy-efficient lighting, with sales of light-emitting diodes (LEDs) reaching one-third of market sales, thanks to major reductions in costs, improved quality and greater options for lighting applications. Sales of LEDs are on track to meet the SDS target, although this will still require a 250% increase in LEDs' share of sales by 2030.

- **Appliances and equipment.** Growing energy use by household appliances shows no signs of slowing down, reaching 2 900 TWh in 2017, or nearly twice as much as the electricity used in Africa and the Middle East. Only a third of appliance energy use today is covered by standards and labels, and coverage is poor in markets expected to grow rapidly in the next decade. Plug-loads and connected devices, which are proliferating rapidly, continue to go unregulated in most countries. All countries should consider adopting energy performance standards while increasing stringency of existing policies and extending coverage to a wider array of products.
- **Data centres and networks.** Digitalization – notably the strong growth in internet traffic, the proliferation of connected devices, and the increasing data intensity of digital media – is driving an exponential growth in demand for data centre and network services. Data centres and networks together account for about 2% of global electricity demand, with huge strides in energy efficiency helping to keep electricity demand flat. Digital companies running the world's largest data centres have also been leaders in corporate renewables procurement, accounting for more than half of total corporate renewable energy PPAs over the past three years.

Building Envelopes

Two-thirds of countries around the world lacked mandatory building energy codes in 2017, meaning that more than the current floor area in the US will be built using less efficient technologies over the coming decade. To meet the SDS target, the number of new high-efficiency buildings being built needs to increase from 75m m2 today to more than 2bn m2 by 2030. Deep energy renovation of existing stock also needs to more than double within the coming decade (with the current rate less than 1%).

A wide range of building policy packages to improve building efficiency were introduced in 2016 and 2017, but those measures were not enough to keep up with rapid growth in global floor area. A handful of countries introduced or updated building energy codes, and several countries implemented building energy certification or incentive programmes. For instance, China released a Standard for Energy Consumption of Buildings in December 2016 that includes prescriptive indicators of actual energy use for various types of buildings. Nigeria launched its first building energy code in September 2017, and the 2007 Energy Conservation Building Code for commercial buildings in India was updated in 2017.

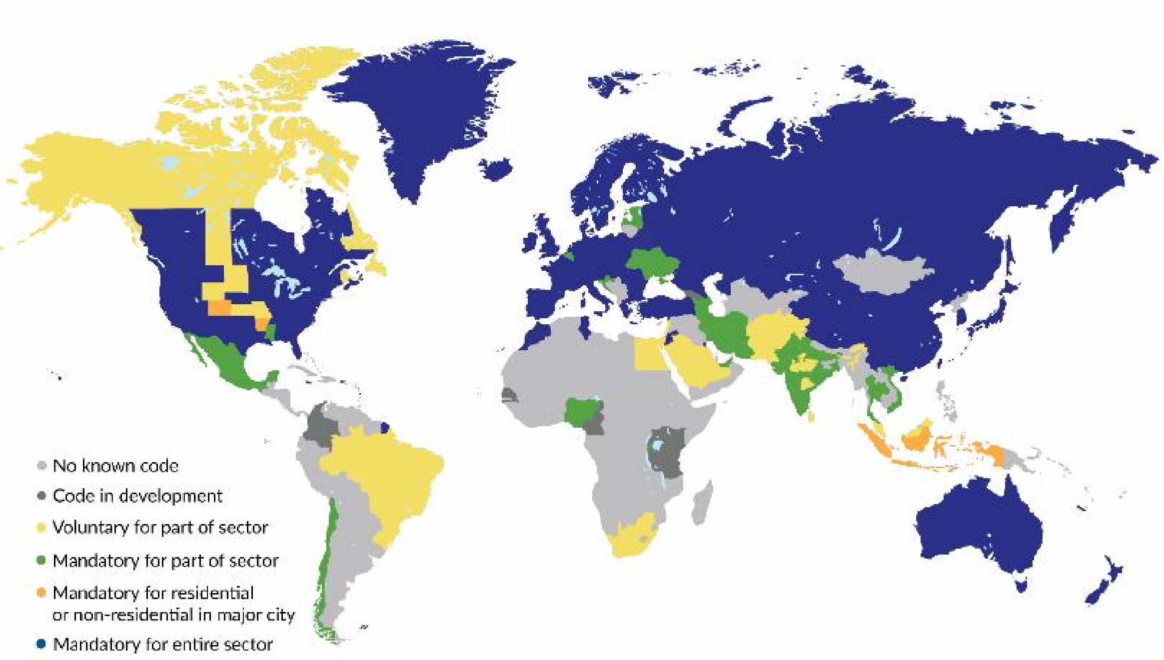

Figure 6: Global Mandatory Building Envelope Code (Source: IEA)

Progress on high-performance buildings construction, such as near-zero energy buildings (nZEBs), has picked up in a few countries, although it still represents a minor share of buildings construction. France is a leader in the nZEB market, with a building code that requires all new construction to fall under its definition of an nZEB. In Austria, Belgium and Italy, more than 20% of residential new constructions in 2017 were nZEBs

On the renovation side, one notable development has been the expansion in 2017 of the Energiesprong programme, which is now present in four countries – France, Germany, the Netherlands and the United Kingdom. This innovative initiative seeks to achieve affordable zero-energy building retrofits.

Building energy certification efforts also picked up in several countries. Canada's Green Building Council launched a dedicated Zero Carbon Building Standard in May 2017, making carbon emissions the key indicator for building performance. In Ghana, the Eco-Communities and Cities National Framework was launched in March 2017 to become an integral part of the National Housing Policy. Brazil's Green Building Council also launched a Zero Energy Standard in 2017, and 11 pilot projects will evaluate the standard across five states.

Progress is being made on other fronts, such as the launch of the voluntary reporting framework levels initiated by the European Union in 2017. A few countries are also working hard to deliver their first national building energy efficiency code, such as Mexico in collaboration with the International Code Council. Building energy codes upgrades also under way in South Africa include differentiation by climate zone.

Building envelope performance improvement is not on track to meet the SDS. Building envelope improvements are critical to achieve the transition to sustainable buildings, but most countries have still not made them an explicit policy priority. For instance, few countries mentioned specific projects or targets related to energy performance standards or efficient building envelopes in their Nationally Determined Contributions submitted as part of the Paris Agreement.

High-performance buildings such as nZEBs typically make up less than 5% of construction in most markets today, representing around 1% of global construction. Typical energy renovation rates are around 1% to 2% of the building stock per year, with average energy intensity improvements generally less than 15%.

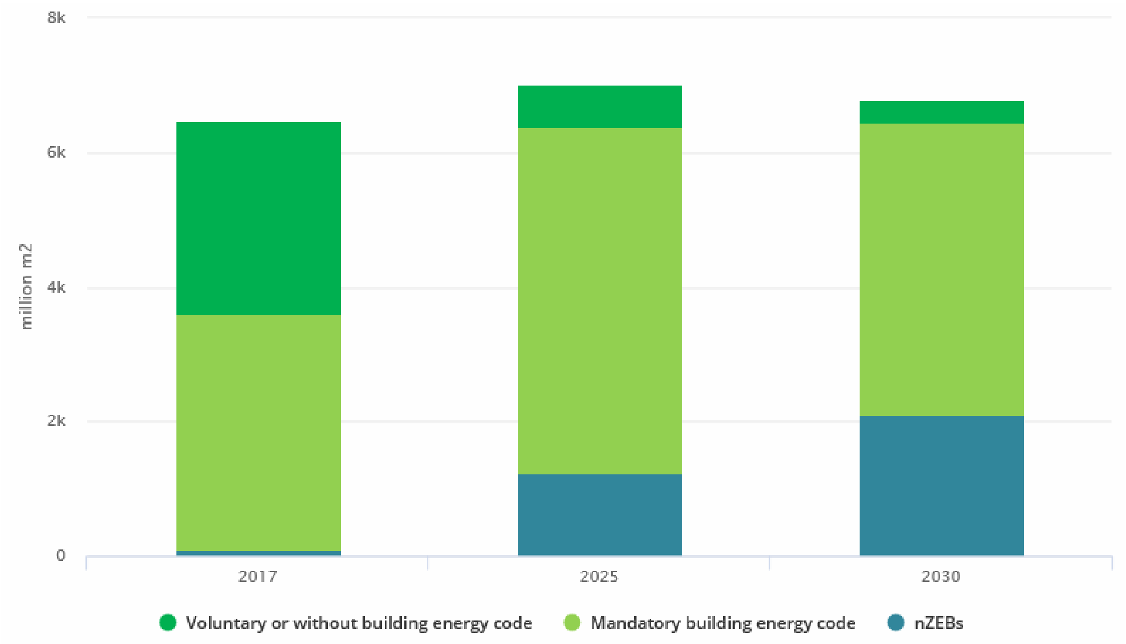

Figure 7: Projected Global Buildings Construction up to 2030 (Source: IEA)

In order to meet SDS goals, high-performance envelopes need to become the construction standard. As of 2017, less than one-third of countries had a mandatory or voluntary building energy code, and only around 80 countries had building energy certifications, including 36 countries with mandatory building energy certification policies and another 20 countries with widespread voluntary building energy certification policies or programmes. Less than a third of countries had building energy certifications in 2017. Building energy certifications also fall short of promoting major change in the buildings market, as they are typically voluntary or only cover a certain number of buildings.

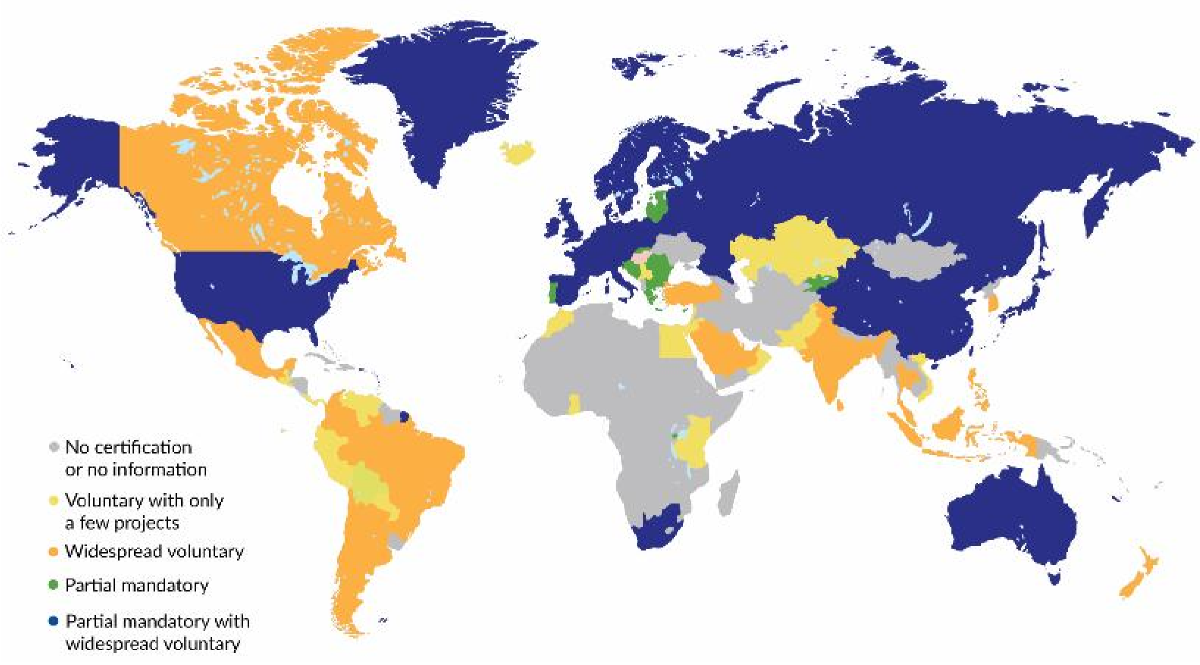

Figure 8: Global Building Energy Certification (Source: IEA)

In 2017 the International Organization for Standardisation published its (ISO) 52000-1 standard for energy performance of buildings, which establishes a systematic and comprehensive structure for assessing building energy performance. But harmonisation is only one step towards the compulsory energy certification that is necessary. Overall, the buildings sector continues to lag behind on envelope performance and is still far from meeting SDS ambitions.

Heating

Sales of heat pumps and renewable heating equipment have continued to increase by around 5% per year since 2010, representing 10% of overall sales in 2017. Fossil-fuel equipment, however, still represents 50% of sales; less-efficient, conventional electric heating equipment represents another 25%. To meet the SDS target, the share of heat pumps, renewable heating and modern district heating needs to reach more than one-third of new sales by 2030. Carbon-intensive and less efficient heating technologies still represent the vast majority of heating sales globally.

Energy use for heating has remained stable since 2010, with heating energy intensities decreasing only by around 2.6% per year since 2010 – roughly the same rate as floor area growth. Much of this is due to energy intensity improvements in major heating markets such as Canada, China, the European Union, Russia and the United States. But fossil fuels still supply most space heating and hot water production needs in buildings. As a result, direct emissions from heating in buildings have remained stable since 2010.

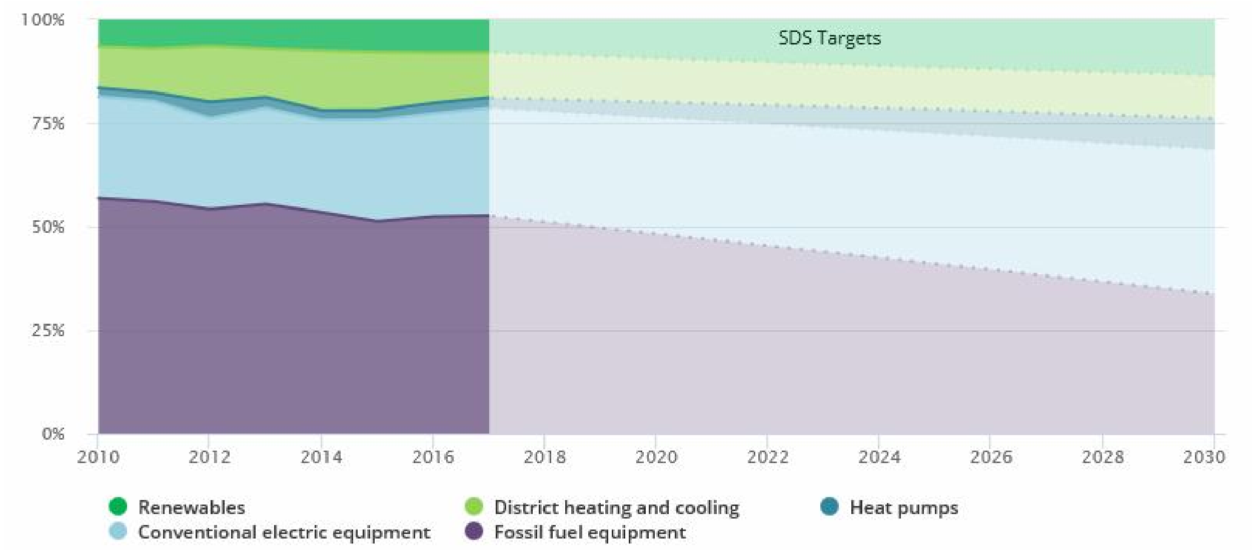

Figure 9: Heating Technology Sales (Source: IEA)

Heating energy intensities are decreasing, but at roughly the same rate as floor area growth. Fossil-fuel based and conventional electric equipment (e.g. electric resistance heaters and electric water heaters, either instantaneous or with a storage tank) continue to dominate the global buildings market, accounting for more than 80% globally of buildings heating equipment stock (excluding traditional use of biomass).

In recent years, condensing gas boilers, with efficiencies often higher than 90%, have gradually displaced coal, oil and conventional gas boilers, whose efficiencies are frequently less than 80%. But progress is not fast enough to meet SDS ambitions, which call for the use of high-efficiency fossil fuel equipment at the very least (e.g. condensing boiler technologies) and require a drastic shift towards clean energy technologies such as heat pumps and solar thermal heating.

Solar thermal heat capacity has increased by 250% over the last decade, and heat pump sales are increasing in many markets. In Europe, heat pump sales increased by 20% in just two years, mainly driven by growth in air-source heat pumps. Yet despite this progress in Europe and elsewhere, significantly greater attention is needed to increase sales of high-performance heat pumps and solar thermal heating in buildings.

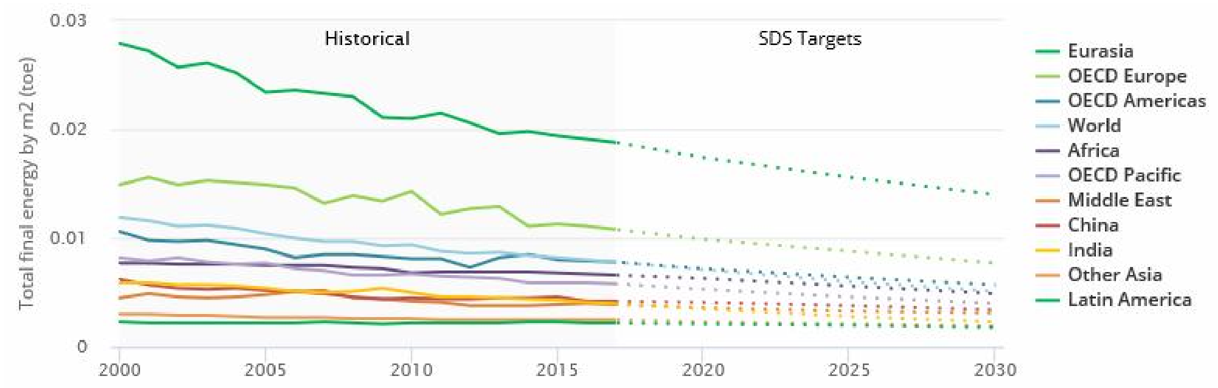

Figure 10: Heating Energy Intensities (Source: IEA)

District heating systems continue to play a large role in meeting heating demand (especially space heating) in many parts of China, Europe and Russia. The number of new connections (approximated here as “sales”) have grown by around 3.5% a year since 2010, driven in particular by China’s extensive district heat network. But significant effort is still needed to reduce the carbon intensity of district heating. China’s reliance on coal for district heat is increasing emissions globally, but increased policy attention to high-polluting production of district heat in the last two years promises improvements in energy and carbon intensities through greater use of industrial excess heat recovery, natural gas and clean coal technologies. In Japan, the number of ENE-FARM hydrogen fuel cell units deployed annually remained steady, with a cumulative installation of 236 000 units at the end of March 2018. Most of these units are installed in single family homes and continue to benefit from subsidy support, which will remain until 2020.

Emissions related to heating in buildings have remained roughly constant since 2010. Sales of heat pumps and solar thermal technologies for heating in buildings are growing, but this is dwarfed by sales of fossil-fuel based heating equipment. To date, only three countries explicitly mentioned heat pumps for water heating in residential or commercial buildings in their Nationally Determined Contributions submitted as part of the Paris Agreement. Twenty-two countries, mostly in the Caribbean, the Middle East and Sub-Saharan Africa, mentioned solar energy as part of their sustainable energy actions for heating and cooling buildings.

To meet the SDS goals, the share of heat pumps and solar thermal heating needs to triple to more than one-third of new heating equipment sales by 2030. Alongside building envelope improvements, deployment of these low-carbon, high-efficiency heating technologies will help increase heating intensity improvements to around 3.3% annually in the coming decade. Improvement will be much faster in heating-intensive countries in Europe and Eurasia.

Low-carbon district heating, potentially providing greater flexibility across energy value chains, can equally support decarbonisation of heating in buildings. But the carbon intensity of district heat – which has remained constant in recent years – needs to improve by around 1% per year. This can be achieved through a combination of low-carbon generation technologies, better management of heat demand (for instance by deploying heat meters and improving building envelopes) and greater flexibility in district energy networks (for example, allowing for input of variable renewable energy and excess heat from industry).

One notable development in 2017 was a proposed collaborative effort by the IEA Technology Collaboration Programmes (TCPs) for Heat Pumping Technologies (HPT TCP), Energy Storage through Energy Conservation (ECES TCP) and other TCPs like District Heating and Cooling (DHC TCP). This collaboration seeks to develop a prototype “Climate Comfort Box” that would deliver high efficiencies with flexible storage at affordable prices in order to deliver on ambitions for affordable heating and cooling under Mission Innovation.

Initiatives to Encourage Debt Finance for Energy-Efficient Households

Several initiatives in Europe and North America offer rebates and lower interest rates on mortgages for energy-efficient buildings. One example is the Energy Efficient Mortgages Action Plan (EeMAP), a project coordinated by the European Mortgage Federation (EMF-ECBC), which has received funding under the EU Horizon 2020 programme to create a private bank financing mechanism to increase energy-efficient investment in EU residential buildings. The project will define a standardised approach for mortgage lenders in the European Union to offer households the possibility of a preferential interest rate and/or additional funds in return for measurable energy efficiency improvement in their property. The initiative hinges on two key assumptions. First, that an energy-efficient property has a higher value.

Second, that borrowers will have more disposable income due to savings on their energy bills as a result of the energy efficiency improvements, and will therefore be less likely to default on their payments (EMF-ECBC, 2016). Increased property value and a lower chance of default make the loan less risky, so these loans could be subject to less stringent capital requirements.

EeMAP looks to build on existing EU-wide energy performance certificates and combine these with additional indicators to provide robust, investment-grade data on building performance. Creating a standardised process for assessing and issuing energy-efficient loans could be a key way not only to unlock debt finance for energy efficiency, but also to create a strong framework to standardise, aggregate and securitise projects. The EeMAP consortium estimates that the project could unlock energy savings of 88 GWh per year, based on upgrades to 35 000 homes that achieve average energy savings of 15%.

On-Bill Financing Assists Low Income Households to Invest in Energy Efficiency

The IEA report that there is opportunity for substantial energy savings in buildings occupied by renters or low-income households. However, many tenants do not meet typical requirements for loans to finance energy efficiency upgrades, especially since such upgrades may be considered financially risky by some banks. This hurdle can be overcome by distribution utilities, which serve all customers, regardless of income, credit history or tenancy status, and can provide finance to homes using “on-bill financing.”

On-bill financing is already being implemented by some utilities, to assist low-income households to overcome the financial barriers to energy efficiency. Customers can accept a tariff that then allows the utility to invest in cost-effective energy efficiency upgrades. Through subsequent bills, the utility can recover the costs of the upgrades via a charge that is less than the estimated savings from the upgrade. The utility’s investment is tied to the electricity meter at the building, so if a customer leaves, the cost recovery is passed on to the new tenant. This can create a challenge for on-bill financing: although the new tenant benefits from the upgrade, they are required to continue paying the charge on their utility bill, regardless of their desire for the upgrade.

This type of on-bill finance is now offered by 12 utilities in the United States, most of which had previously offered on-bill loan programmes. However, those programmes did not reach low-income market segments (Energy Efficiency Institute). To date, utility commissions in four US states have approved on-bill financing, some of which have service areas recognised for persistent poverty. Altogether, utilities in these states have reported making more than 2 000 investments, totalling over $20m, with only 0.1% of charges uncollected.

Use of Building Codes: Jakarta Case Study

Beyond standards for efficient lighting and air conditioners, the potential to use standards to boost efficiency and save energy in whole buildings has been exploited by the cities of Jakarta and Bandung through “green building” codes. Alongside national energy efficiency standards for individual building components, the cities of Jakarta and Bandung have developed and implemented local whole-building green building codes that include energy efficiency requirements.

Both cities have mandatory requirements for large buildings, while Bandung also has building code requirements that incorporate energy performance and incentives for small buildings.

Currently 412 of 508 local jurisdictions in Indonesia have some form of building regulation in place, which provides an important regulatory framework that could enable the inclusion of future energy efficiency requirements. In addition, the Ministry of Public Works and Housing has developed a policy for green buildings, with a 2015 decree that requires buildings of more than 500 m2 to meet minimum energy performance requirements.

Jakarta was the first city in Indonesia to develop and implement a green building code for large buildings. The code, which includes checklists and forms on the city website, is for green design, construction and operation, with reporting required every five years to obtain an extension on the building occupancy permit. However enforcement is a challenge and compliance issues need to be addressed.

Bandung was the second city in Indonesia to develop a green building code. Launched in 2016, the Bandung green building code goes a few steps further than the Jakarta code by being applicable to all buildings, with mandatory measures for large buildings and voluntary measures for all other buildings to achieve 1-star level compliance. The Bandung code also includes additional sustainability measures to achieve 2- and 3-star level compliance, with the opportunity to receive financial incentives. In addition, Bandung has implemented two innovative green building code policies, providing online tools for reporting and a sampling verification procedure.

Jakarta and Bandung's green building codes have created the basic framework, tools and policy understanding that can encourage more widespread adoption and enforcement of energy efficiency requirements for buildings across Indonesia. With the support of the city's leaders, Bandung has been able to demonstrate to Indonesia the next step in improving building code development and implementation across all buildings.

International Trends in Energy Integration

The text below relates to the IEA's progress reporting concerning the 'energy integration' sector which includes energy storage, smart grids, demand response and digitalisation aspects.

While individual clean energy technologies are the building blocks to clean energy transitions, a variety of "energy integration" technologies – such as smart grids, energy storage, and hydrogen – will also need to play an increasingly important role to maximise the collective impact of individual technologies and bring the world onto an SDS trajectory. Some areas are seeing signs of progress, but overall, these increasingly crucial integration technologies need more innovation and policy focus.

Meeting the SDS goals will require scaling up of technologies that help different parts of the energy system work together. Though many of them are making progress, none of these important technologies is fully on track to meet the SDS goals

General Trends in Energy Storage (utility scale)

While battery prices fell by 22% from 2016 to 2017, continuing a very positive trend, additional utility-scale deployments for all storage technologies (excluding pumped hydro) remained flat in 2017 at around 620 MWh. This 2017 deployment rate is insufficient to meet the SDS target, which requires an additional 80 GW of overall storage capacity added by 2030. Additional policy support and ensuring a wider range of storage technologies become cost-effective are crucial.

General Trends in Smart Grids

Investment in smart grid technologies grew by 12% between 2014 and 2016 overall, but key areas such as smart distribution networks are lagging behind, with investment growing by only 3% in 2017.

Progress in smart meter deployment is uneven across countries, with further regulatory change and new business models needed for smart grids to play their critical integration role in clean energy transitions.

Smart grids comprise a broad mix of technologies for modernising electricity networks, extending from the end-user to the distribution and transmission levels.

At the end-user level, smart grids can enable demand flexibility and consumer participation in energy systems, including through demand response, electric vehicle charging and self-produced distributed generation and storage.

Demand flexibility can increase the overall capacity of the system to host variable renewables while accelerating the electrification of heating, cooling and industry at lower costs. Deploying a physical layer of smart grid infrastructure – underpinned by smart meters – can help to unlock these benefits.

General Trends and Opportunities in Demand Response

The IEA's World Energy Outlook 2017 estimated that globally, the theoretical potential of demand-side response to be nearly 4,000 TWh per year, or more than 15% of total electricity demand. In the central scenario of the World Energy Outlook 2017, annual demand-side response potential is expected to increase to almost 7,000 TWh by 2040, the buildings sector leads future growth as demand for appliances and electric heating and cooling expands in Asia and Africa. Within developed economies, the electrification of heating and transport are major drivers of future growth. Smart charging of electric vehicles (EVs) uses charging (and discharging) of EV batteries to facilitate balancing of the power grid.

Policies to facilitate demand response are emerging in a number of regions, but only a small share of the full potential is being used today.

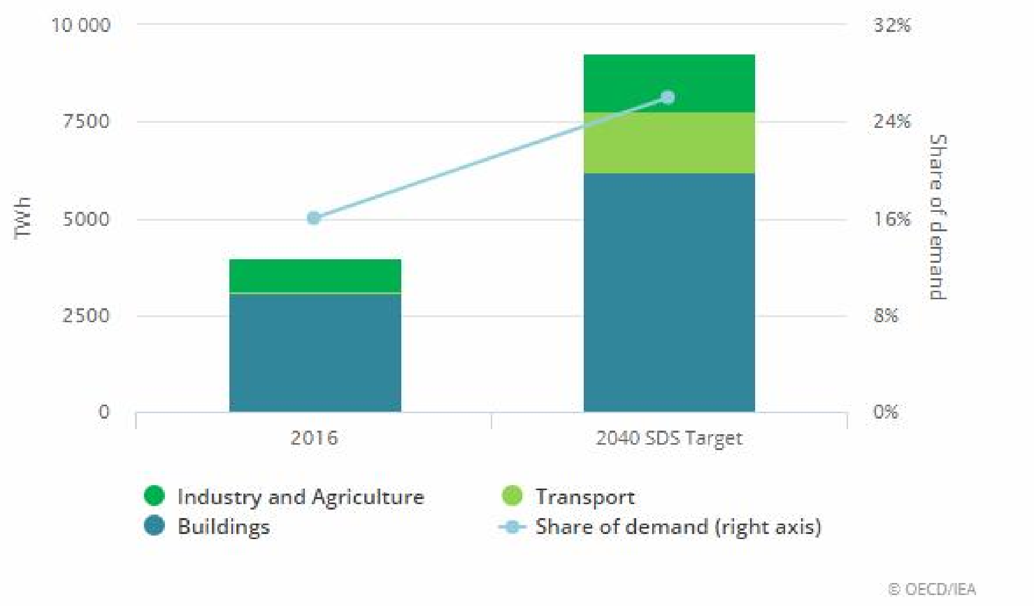

Figure 11: Global demand response potential (source: IEA)

The IEA estimates that by 2040 almost 1 billion households and 11 billion appliances could participate in demand response programmes. While the majority of potential may lie in buildings, this potential can also be the most difficult to tap. This is especially the case in residential buildings, where participating in demand-side response programs may require behaviour change while offering limited economic benefits to households due to the small size of residential loads. As such, aggregation and automation of small scale demand-side response resources is often the most viable path to market for the residential sector.

The demand-side response potential in industry and large commercial buildings can be more accessible, as energy management systems optimize decisions to consume electricity or offer demand-side response services to the market.

Connectivity as a key enabler

Digital connectivity is the key to expanding demand-side response into new sectors and realising a greater share of its total theoretical potential. By enabling the linking, monitoring, aggregation and control of large numbers of individual pieces of electricity consuming equipment, connectivity allows for matching demand to the needs of the overall system in real time. Smart meters, smart appliances, electric vehicles and load management software are therefore central to efforts to increase demand-side response resources.

Capitalizing on demand-side response potential also requires appropriate price signals and regulatory frameworks to incentivize participation. Retail tariff structures such as time-of-use pricing or real-time pricing can deliver the necessary price signals to consumers, while enabling aggregators and other demand-side resources to participate in wholesale energy, capacity and ancillary services markets can create the necessary environment to stimulate investment.

Demand-side resources active in markets today represent only the tip of the iceberg in terms of the total potential. Digitalisation presents an opportunity to unlock this enormous potential and significantly enhance grid flexibility. As prices for digital technologies continue to fall and electricity consuming equipment is increasingly connected and controllable, expansion of demand-side response becomes technically feasible and economically attractive.

Electricity consumers benefit from reduced electricity bills by providing demand response services, but even larger savings are realised on a system level. Digitally enabled demand response is often a more cost-effective and climate-friendly measure facilitating the integration of variable renewables than building new power plants or electricity storage. Rapid expansion will act as a key accelerator for the clean energy transition. Moving forward, government policy will need to provide clear rules and a long-term vision for increasing demand-side response resources.

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Smart Meters

Smart meter deployment has seen great strides in recent years in a few key regions. China is approaching full deployment, and Japan, Spain and France are poised to reach full rollouts over the next few years. The United States and the European Union as a whole have reached over half of the market.

Smart meter deployment has grown rapidly, with several countries poised to reach full rollouts over the next several years.

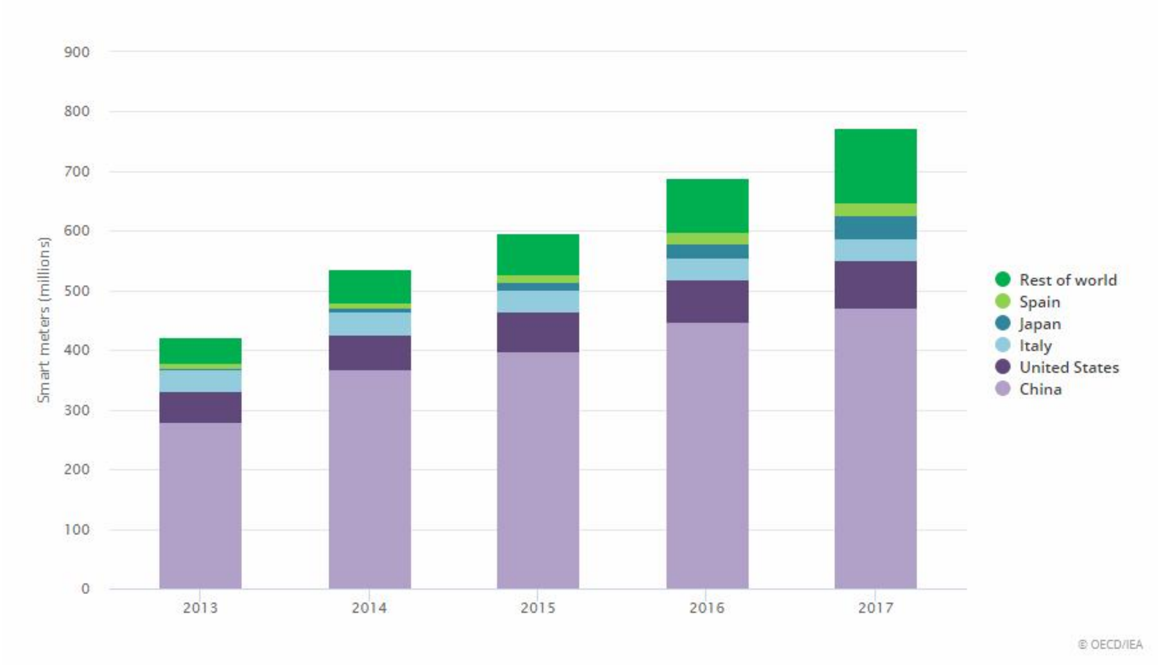
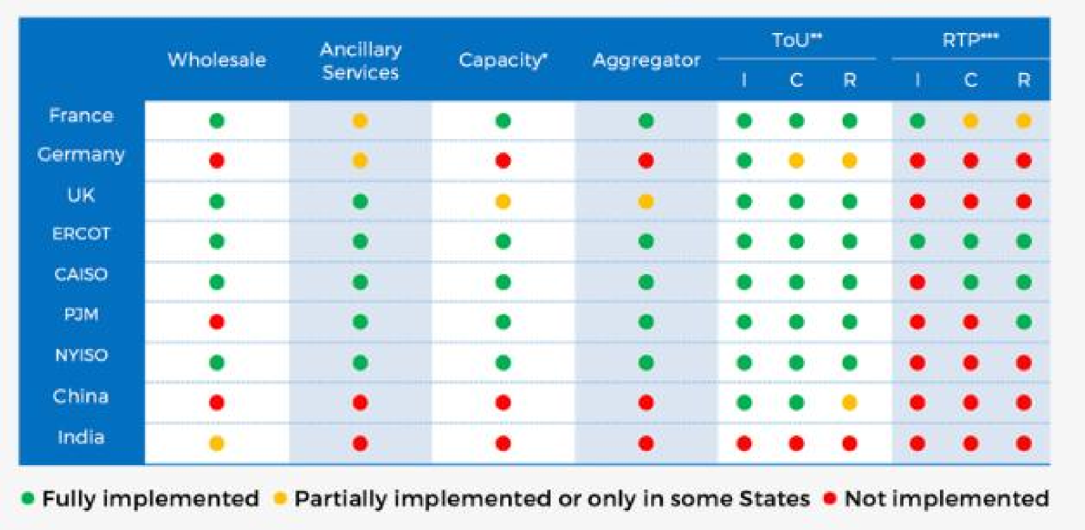


Figure 12: Global Cumulative smart meter roll-out (source: OECD / IEA)

Demand Side Response

Traditionally demand-side response has been confined to large-scale industrial consumers manually shedding demand in times of system stress. However the IEA report over 75% of the global potential in demand-side response lies in buildings, with space heating, water heating and air conditioning loads contributing the most. The thermal inertia of buildings and hot-water storage allows electricity demand from heating and cooling equipment to be shifted in time to suit the needs of the grid at low cost without compromising user comfort. Loads from appliances such as refrigerators and washing machines can also become demand-side response resources, facilitated by the growing market share of smart appliances.

Expanding demand-side response – beyond manual shedding of large loads – is a relatively recent phenomenon, with Europe and the United States currently leading growth. In several markets consumers can receive payment for various forms of short-duration “fast frequency response” to keep the grid in balance, larger volumes of “load shifting” to respond to changeable weather, or contracts for guaranteed changes to future consumption patterns.



	Wholesale	Ancillary Services	Capacity*	Aggregator	ToU**			RTP***		
					I	C	R	I	C	R
France	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟡	🟡
Germany	🔴	🟡	🔴	🔴	🟢	🟡	🟡	🔴	🔴	🔴
UK	🟢	🟢	🟡	🟡	🟢	🟢	🟢	🔴	🔴	🔴
ERCOT	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
CAISO	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢
PJM	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢
NYISO	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴
China	🔴	🔴	🔴	🔴	🟢	🟢	🟡	🔴	🔴	🔴
India	🟡	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴

🟢 **Fully implemented** 🟡 **Partially implemented or only in some States** 🔴 **Not implemented**

Figure 13: Current status of demand side response in selected electricity markets (source: IEA)

Notes: I, C and R refers to industrial, commercial and residential consumers. * Where no capacity market is present, day ahead reserves and other market products used to guarantee supply are included. ** ToU refers to time of use pricing. ***RTTP refer to real time pricing including critical peak pricing where the time and price of peaks is not predetermined. ERCOT, CAISO, PJM and NYISO are major electricity interconnection regions within the United States.

Key Areas of Innovation

As countries seek to both shrink both their energy consumption and carbon footprint, improving the energy efficiency of buildings is being given high priority. Thousands of buildings are planned for renovation in the coming years, and more will be constructed or refurbished when stricter EU guidelines come into effect (e.g. in the EU in 2020).

In response, the energy-efficiency building sector is growing rapidly, especially in Europe. The European efficiency-related construction market is expected to be worth €140bn by 2020. Over the past decade the number of related intellectual property (i.e. patent) filings has tripled. The European Patent Office has identified four areas of building-related energy efficiency technologies in which innovation (measured by proxy by patent applications) is concentrated: heating and cooling; insulation; efficiency lighting; and self-powered buildings.

Heating and Cooling

About half of a building's total energy is devoted to heating, ventilation and air-conditioning (HVAC). So it is hardly surprising that the field has become a focal point for innovation. One of many promising HVAC patent areas is air purification, which incorporates technologies such as ultraviolet light and photo-reactive chemicals similar to those that occur in the Earth's atmosphere. Such systems enable buildings to reuse large amounts of their internal air and help lower heating costs.

Another up-and-coming field is passive solar and radiant heating, where warm, sunlit air is diverted to heat a building or, during the summer months, used to draw in colder air for ventilation. Such passive solar designs are used in many high-efficiency buildings, including the large glass dome of the German Bundestag in Berlin and the new Raiffeisen RHW-2 building in Vienna.

Insulation

Energy-efficient heating can only keep a building warm if there is sufficient thermal insulation to keep the heat inside. Many commonly used, high-efficiency insulators were developed several decades ago and have seen gradual improvements and refinements since. These include insulating concrete forms (ICFs), the brainchild of German-Canadian engineer Werner Gregori. ICFs use interlocking polystyrene concrete forms to create a seamless wall through which air cannot penetrate.

Structural insulated panels (SIPs) are another frequently used insulation option, partly because they can be integrated into a number of materials, including particle and gypsum board, sheet metal, plastics and foams. They work by sandwiching insulation into interlocking sheets of building material to create uniform coverage.

A new type of insulation, which employs a different thermal principle, has been creating a small sensation in the field since its emergence a little more than five years ago. Unlike typical insulation that traps air in pockets, often between strands of fibrous material to resist the flow of heat, phase-change materials (PCMs) absorb or discharge heat as they change back and forth from a solid to liquid state. In a sense they "melt" and "freeze" at conditions close to room temperature and draw in or release heat in the process.

Efficient Lighting

Keeping our homes and workplaces well lit eats up energy as well - somewhere between 10 and 30% of a building's total energy consumption. The number of innovations to develop more efficient lighting technologies is growing at an incredible rate.

Numerous LED (light emitting diode) and OLED (organic light emitting diode) applications promise to make a big dent in the amount of energy spent on lighting. LEDs require about one tenth of the energy of incandescent light bulbs and roughly half of that of the compact fluorescent lights (CFLs) which are standard in Europe. They also last at least 40 times longer.

2007 EIA finalist Shuji Nakamura was part of a team of scientists that created the first LEDs to emit blue light, which paved the way for all colours, including white, to be produced. British scientists and 2006 EIA finalists Richard Friend, Jeremy Burroughes and Donal Bradley created the first OLEDs, whose slim size allows them to be incorporated into building materials such as tiles and transparent window-like materials that allow in the sun's rays during the day and illuminate at night.

Self-Powered Buildings

The transition to true green buildings - the realm of net-zero-energy construction and beyond - will not be complete until such structures are not only extremely efficient, but also produce enough power to cover their own energy requirements and even send excess energy back into the power grid. Here, solar and wind power are promising technologies, and various innovations that help integrate these technologies into buildings.

Skyscrapers provide ideal locations for roof-mounted wind turbines. Thanks to nearly constant air currents at higher altitudes, turbines can generate a considerable portion of a building's own power requirements. Solar power is a more widely tested method for buildings to create renewable energy. Photovoltaic cells are found not only on rooftops but also on building facades and even in transparent modules used as windows and skylights.

One of the more striking examples of the clever incorporation of solar- and wind-power technology is the refurbished CIS tower in Manchester, England. It relies on a photovoltaic skin to generate up to 180,000 kWh of electricity per year and has two dozen wind turbines that produce about one tenth of its energy requirement.

Future Growth in Energy Efficiency in Buildings

Energy Efficient Building Materials

The global “green building materials” market size is expected to reach $364.6bn by 2022.[36] Growing demand for environmental-friendly and sustainable building materials is expected to propel the growth of the market.

Green building materials prevents the usage of toxic paints containing lead, in turn improving indoor air quality. Furthermore, the products also offer plentiful natural lighting thereby reducing energy usage which thereby reduces the overall expenditure. Copious raw material availability coupled with a large number of manufacturers is expected to aid the growth of market.

Technological innovations have facilitated a rise in demand in green building materials, as products are becoming increasing affordable and readily available. As a result, the demand has increased dramatically over the past few years majorly due to rebounding construction market.

Increasing demand for green building materials coupled particularly in emerging economies is expected to have a positive impact towards market growth. In addition, presence of large number of manufacturers is expected to increase the ease in sourcing the products. Oversupply of green building materials is expected to lower product price which is expected drive the market growth over the forecast period.

The market exhibits the presence of a large number of manufacturers engaged in the manufacturing of wide range of products including roofing, insulation, and frames. Easy accessibility to raw materials coupled with product demand is likely to increase industry rivalry which is expected to improve product quality.

- Structural product segment is expected to reach $239.1bn by 2022, owing to their superior aesthetics, and durability, and ability to reduce carbon emissions.
- Insulation is estimated to be the fastest growing application with a growth rate of 11.7% over the forecast period, on the account of its high energy efficiency coupled with heightened emphasis on the installation of interior insulation solutions
- The demand for the product in Asia Pacific is expected to reach a value of $78.4bn by 2022 in the wake of rising residential construction and growing infrastructure development.
- Manufacturers primarily focus on the production of standard products for consumers. However, customizations as per consumer preference are expected to be the way forward which in turn is anticipated to propel demand.

Heating

The global space heating equipment market was worth $28.85bn in 2015 and is expected to witness considerable growth owing to the growing preference for energy efficient solutions.[37] Rapid industrialization coupled with increasing repair and renovation activities in the residential sector is projected to drive the demand for heating systems over the coming years.

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[36] Grand View Research (2018).

[37] Grand View Research (2016).

One of the major trends influencing the heating equipment market is demand for products that are certified as energy efficient. Growing energy consumption in the industrial and residential sector is projected to drive the demand for solutions that decrease operation cost and enhance energy savings.

The heating equipment industry is highly competitive, and companies are at the risk of losing business owing to several factors including price, technology, product performance, geographic presence, and customer service. District heating solutions are expected to gain prominence over the coming years.

Heat pumps accounted for 42.7% of the global revenue in 2015. Heat pumps are also known as two-way air conditioners as it helps extract heat from cold outdoors with the aid of an electrical system, and discharges that heat inside the house. Heat pumps are projected to grow at rapidly on account of its low operating cost and high operating capacity. Furnaces are the most common heating system used in the residential sector across the world. The demand for furnaces is anticipated to grow rapidly on account of its quick warming capability, easy availability of replacement part, and energy efficiency.

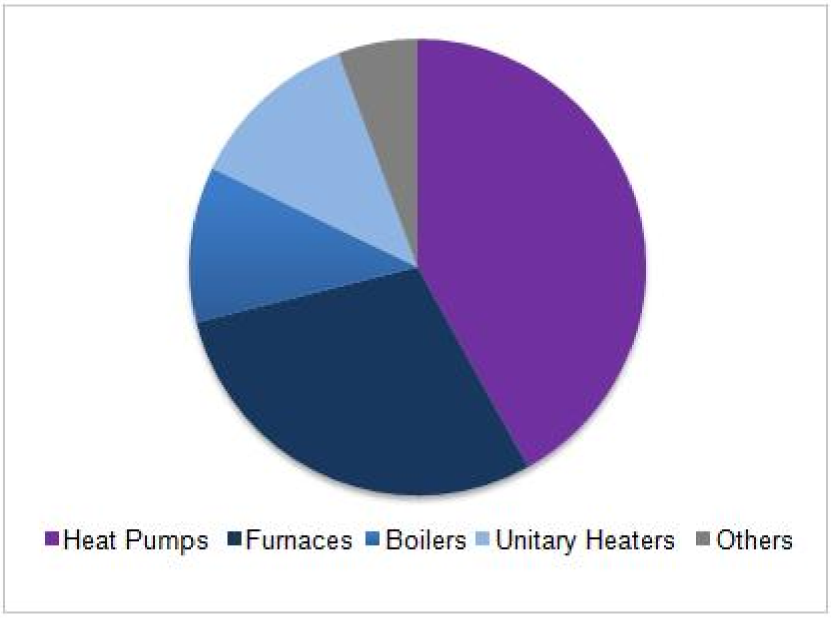

Figure 15: European Heating Equipment Forecast Market Share 2025 (Source: Grand View Research)

The industrial application sector is projected to grow more rapidly over the next decade. Industrial buyers focus on factors such as energy and operational cost savings, maintenance cost, and product lifespan. However, residential buyers seek energy-saving solutions at economical prices.

The residential sector utilizes heating systems for space and water, and other utility purposes. Growing repair and renovation activities undertaken in North America and Europe coupled with increasing construction spending in the Asia Pacific and Middle Eastern region is projected to propel the demand for heating solutions over the coming years.

Europe is projected to experience high demand for energy-efficient and certified products. Favorable government policies related to reducing energy consumption are expected to boost the preference for technologically upgraded products and solutions. Demand from the Asia-Pacific region is projected to grow at the fastest rate in the medium term. Rapid industrialization and increasing R&D efforts to develop energy-efficient solutions is anticipated to lead to an acceleration in growth in demand over the coming years.

Some of the major companies include Danfoss, United Technologies Corporation, Ingersoll-Rand Plc, Lennox International, Inc., Daikin Industries Ltd., Johnson Controls, and Robert Bosch GmbH. Other prominent players in the industry are Uponor Corporation, Emerson Electric Co., Honeywell International Inc., Pentair PLC, Nexans S.A., Schneider Electric SE, Siemens AG, Mitsubishi Electric Corporation, and Nortek, Inc. The industry is expected to influence continuous product developments in terms of energy efficiency, remote accessibility, and ease of operation. New product developments and investments in new production facilities and distribution channels are some of the strategic initiatives taken up by companies.

Appendix C Online survey question-set

An electronic copy of the survey has been provided to Scottish Enterprise.

Appendix D Consultation question-sets

An electronic copy of the consultation question-set has been provided to Scottish Enterprise.

Report Ends