# Scottish Enterprise

## Assessment of Scotland's opportunities within digital heat technologies

February 2023

RAMBOLL

Bright ideas.
Sustainable change.

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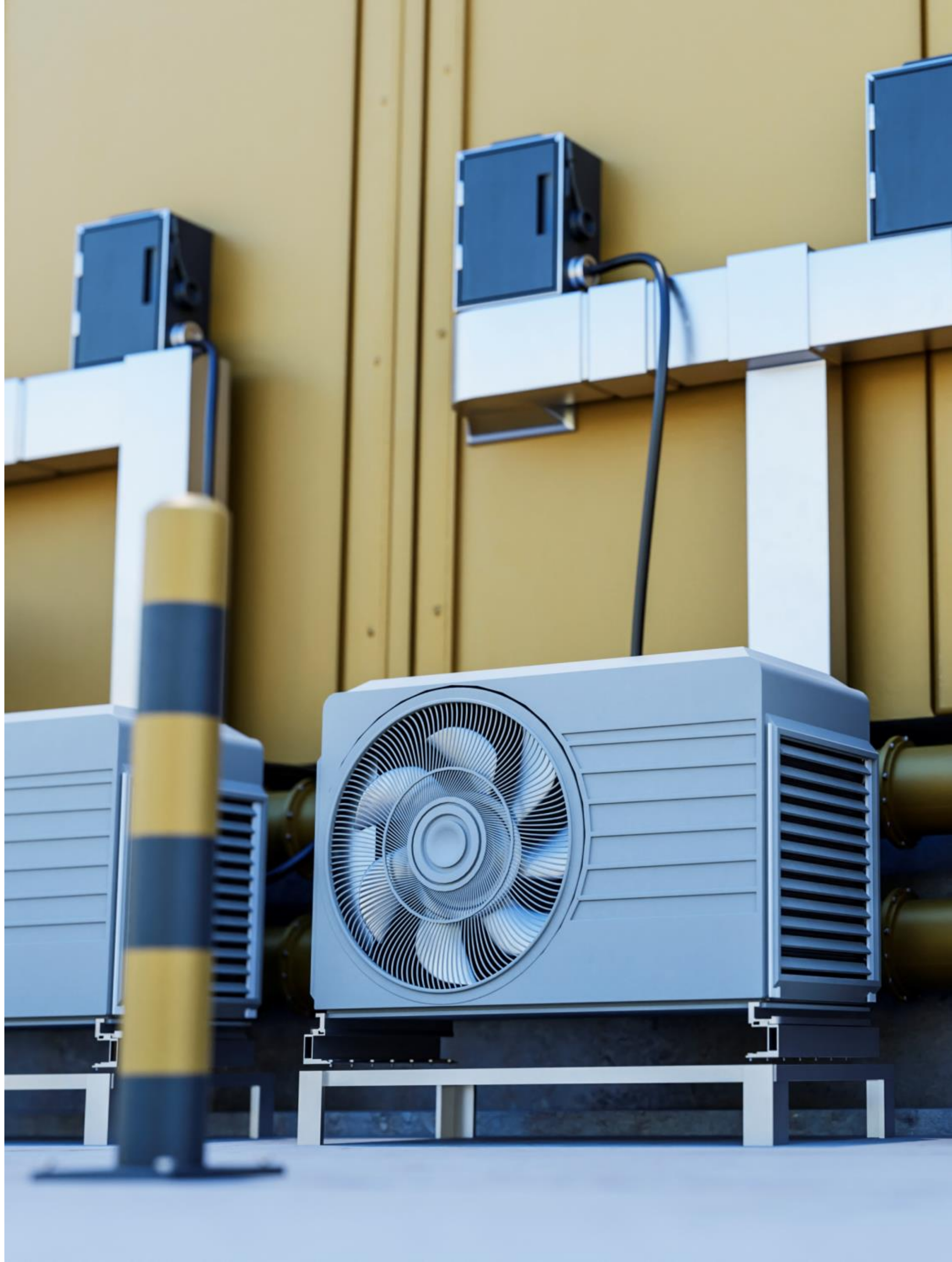

# Glossary

| Abbreviation | Definition |
|---|---|
| AI | Artificial Intelligence |
| ML | Machine Learning |
| IoT | Internet of Things |
| HVAC | Heating, Ventilation and Air Conditioning |
| BEMS | Building Energy Management System |
| HNMS | Heat Network Management System |
| HP | Heat Pump |
| GUI | Graphical User Interface |
| SUI | Smart User Interface |
| AC | Alternate Current |
| DC | Direct Current |
| HVDC | High Voltage Direct Current |
| IES | Integrated Environmental Solutions Ltd |
| PNDC | Power Networks Demonstration Centre |
| GVA | Gross Value Added |
| EA | Energy Audits |
| EAP | Energy Action Plan |
| EPC | Energy Performance Certificate |
| DEC | Display Energy Certificate |
| RHI | Renewable Heat Incentive |
| SME | Small and Medium-sized Enterprise |

| Abbreviation | Definition |
|---|---|
| SE | Scottish Enterprise |
| DH | District Heating |
| CHP | Combined Heating and Power |
| WtX | Waste-to-X |
| STEM | Science, Technology, Engineering and Mathematics |
| DUR | Danish Utility Regulator |
| ESCO | Energy Service Company |
| ICT | Information and Communication Technology |
| EESSH | Energy Efficiency Standard for Social Housing |
| GHG | Greenhouse Gas |
| ESOS | Energy Savings Opportunity Scheme |
| SECR | Streamlined Energy and Carbon Reporting |
| BMS | Building Management System |
| ESG | Environmental, Social, and Governance |
| HaaS | Heat as a Service |
| LHEES | Local Heat and Energy Efficiency Strategies |
| SWOT | Strength, Weakness, Opportunity and Threat |
| SG | Scottish Government |
| DNO | Distribution Network Operator |

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# The present position of the Scottish digital heat tech industry can be visualised through the SWOT framework

| *INTERNAL* | *EXTERNAL* |
|---|---|
| **STRENGTHS**<br>• National **data gathering** initiatives, specific **policies for zero-carbon** heat and specific regulations on optimisation of **heat in buildings**<br>• Renowned **engineering universities** with dedicated **R&D institutes** and **public-private** collaborations<br>• Scottish start-ups and SMEs working on **advanced tech**, benefitting from **digital clusters** in the biggest cities and strong **innovation centres**<br>• Some state **funding for digital tech** lowering the investment cost | **OPPORTUNITIES**<br>• Net-zero policies to **phase out gas, electrify heat, improve building stock** and develop **integrated grid,** especially the UK-wide smart meter rollout<br>• **Increasing gas prices** and electrification of heating systems<br>• Growing **demand** from the **residential** sector due to increasing energy prices and **opportunities to retrofit** energy-saving technologies<br>• **New business models** in the sector and increased **awareness** among private consumers<br>• **Collaboration** between engineering and digital tech clusters<br>• **Inward investment** into the industry development |
| **WEAKNESSES**<br>• Lack of **policy coherence** and facilitation of **data** collection<br>• **High electricity costs** posing a barrier to low carbon heat (e.g. heat pumps)<br>• No specific R&D focus and **missing digital** and **cross-sector skills**<br>• Early development of the **market** and the digital **infrastructure**, where international corporations dominate and there are no dedicated **network** organisation<br>• Lack of targeted **funding and resources** for low-carbon heat tech development by **Scottish SMEs** | **THREATS**<br>• No **platform** for **data collection and sharing**<br>• Insufficient number of **Scottish companies with enough resources** to supply the market<br>• **Lack of interoperability** between systems and technologies and no incentives to share data<br>• **Lack of urgency** to meet the decarbonisation goals and no demand drivers due to **limited interest and awareness**<br>• **Lack of consumer awareness** of the cost-benefits of heat tech<br>• **High investment cost** for advanced technologies such as BEMS |

**SWOT**

STRENGTHS

# Scottish industry is supported by dedicated policy focus, allowing it to utilise its potential in R&D and digital tech

**What are the strengths in the SWOT framework?**

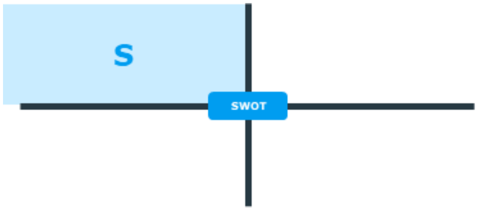
Strengths explain what the Scottish industry excels at and what sets it apart from the competition. It focuses on internal strengths and unique capabilities, such as R&D, regulations, industry structure, and funding opportunities.

**Key questions to consider:**

What do you excel at?

What distinctive resources do you have?

What are your strongest points?




## Regulations

- **National data gathering initiatives** due to the deployment of Smart meters as well as the development of databases due to supportive regulation.
- **Specific policies for zero-carbon heat** like Heat in Buildings Strategy, LHEES, and Heat Networks Act.
- **Improving building regulations** creates a push for collecting building performance data and improving heat efficiency.

## Resources

- Renowned **engineering programs** with international recognition.
- R&D through dedicated **research activities** in heat engineering and digital technology at universities.
- Existing **collaborations** between universities and private companies in Glasgow, Edinburgh, and Aberdeen.

## Industry

- A growing industry in digital technologies for low-carbon heat with many Scottish **start-ups and SMEs** working on advanced tech, where most companies are developing multiple technologies.
- **Digital clusters** in the biggest Scottish cities with attractive tech communities.
- **Strong innovation centres** across all needed areas of expertise for digitalising heat: Innovation Centre for Construction, Sensing & IoT, and Data & AI.

## Funding

- Various governmental funding opportunities attract the demand side aiming at **lowering the investment costs** and **targeting various stakeholders** such as private consumers, social housing, communities, SMEs, and larger organisations. Their focus is primarily on low-carbon heat adoption, which subsequently drives demand for adjacent digital technology.

WEAKNESSES

# An early stage industry and legal framework are barriers to achieving the lead within digital heat tech

**What are the weaknesses in the SWOT framework?**

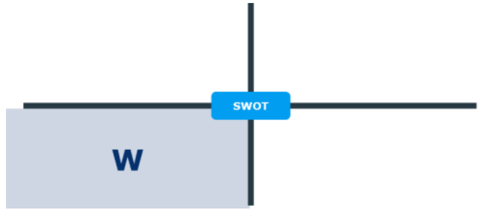
Weaknesses prevent the industry from operating at its best. A bad policy framework, industry structure, and missing skill gaps are examples of areas where the country must improve in order to remain competitive.

**Key questions to consider:**

What might you do better?

Where do you have fewer resources?

What are the industry flaws?




## Regulations

- **Lack of policy coherence** regarding future heating systems, as the state's policies and goals have changed a lot over the years.
- **High taxes on electricity** consumption resulting in price disparity and a lack of economic advantage of low-carbon heating technology.
- **Building regulations and data on housing stock are poor** and not standardised and advanced enough for the deployment of digital technology.

## Resources

- **R&D lacks a specific focus** on combining digital and engineering research aspects in their dedicated research initiatives.
- **Human capital** lacks basic and advanced digital skills, installation skills relevant to hardware which is more complex than heat pump installation, and sector-specific skills bridging the knowledge gap between digital, heat, and engineering.
- **Digital infrastructure** is not developed for the heating sector and there is a lack of common standards across sectors and actors.

## Industry

- **No large Scottish companies** doing digital technologies for heating, where the market is dominated by large foreign companies.
- **Advanced technologies** are at an early stage of development and mostly by SMEs with limited resources.
- **Lack of network organisation** combining low-carbon heating with the digital sector.

## Funding

- **Most state funding programs are** not targeting suppliers of the technology, whereas it is not profitable to expand their product portfolio or invest in R&D, especially considering the high number of SMEs. Apart from dedicated funding from Scottish Enterprise, the governmental grants are targeting lowering the investment costs.

OPPORTUNITIES

# The decarbonisation goals and phasing out gas create opportunities in the market

**What are the opportunities in the SWOT framework?**

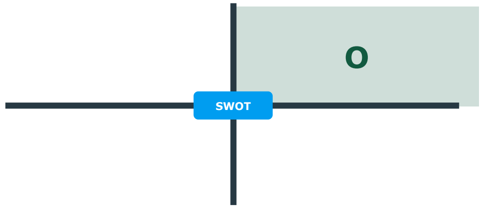
Opportunities are favourable external conditions providing a competitive edge. In the context of the report and its analysis, it is all regulations, trends, market, and demand conditions that are not directly addressing low-carbon heat but can be used as a catalyst for its growth.

**Key questions to consider:**

What are the external opportunities?

What trends could you capitalize on?

What are the supportive market conditions?




## Regulations

- **National net-zero goals** as Scotland has an high ambition to reduce $CO_2$ emissions, especially from heating which is the primary source.
- **Regulations are focused on improving the heat** efficiency of the building stock as well as the methodology behind data collection.
- Regulations are pushing for the **industrial sector to cut emissions**, especially from energy usage.

## Trends

- **Electrification of heat and grid integration** as a way to decarbonise the power market in the UK and EU.
- **New business models** to facilitate the uptake and enhanced demand for digital technologies such as one-stop shops, collective purchasing, and HaaS.

## Market conditions

- **Commonly used gas boilers** are banned from 2024 making the switch to low-carbon heat systems more economically viable.
- **Increasing electricity and gas prices** push both residential and industrial sectors to cut on power demand and cost, often by implementing digital technologies.
- Political ambitions and goals supported by funding schemes aimed at accelerating industry development could drive **inward investments** into Scotland and make it attractive so set up local operations.

## Demand conditions

- **Growing demand** from the residential sector due to retrofitting and increasing focus on energy performance.
- Increasing number of **private consumers monitoring their heat performance** and using digital tools (also due to a more customer-friendly interface).

THREATS

# Lacking framework for data sharing and interoperability are the present threats to future development

**What are the threats in the SWOT framework?**

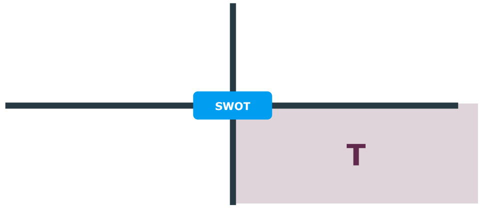
Threats are variables that have the potential to hinder the development of the industry. In the context of the report and its analysis, it is all the factors that are resulting in decreasing the economic, market, and policy opportunities for low-carbon heating digital technology.

**Key questions to consider:**

What are the potential dangers and threats?

What can shift the market focus?

What are the missing gaps in the industry?




## Regulations

- **No centralised platform for collecting and sharing** customers, consumption and price data as well as facilitating data communication between market participants in the grid.

## Trends

- **Lack of urgency** on both the supply and demand side, where not enough companies with sufficient resources are available and the market is slow to increase the scale of digital technologies to meet national decarbonisation goals in Scotland.
- **Costs of some products** such as Building Management Systems (BMS) and digital twins are too high for smaller companies and still haven’t seen significant price reductions.

## Market conditions

- **Lack of interoperability** between systems and their actors and no present market incentive to collaborate on data sharing and technological standardisation.
- **Lack of companies with enough resources** to develop and optimise new products, especially in the realm of advanced technology.

## Demand conditions

- **Lack of natural demand drivers**, where the regulators and funding schemes are the main catalysts for the use of digital technology, where the market interest is limited due to high investment cost and the early product offering development.
- **Lack of interest in the technologies** due to education gaps from private consumers and corporations, especially SMEs.

# Four primary drivers and collective collaboration of key actors are key to develop the Scottish industry

Scotland has set an ambitious target of reducing carbon emissions by 75% by 2030. Decarbonising heat through the application of digital technologies will play a crucial role in achieving this target.

Having the lowest rate of decarbonised heat of any country in Europe combined with ambitious decarbonisation targets and supporting public investments provide an opportunity for Scotland to develop its industry within low-carbon heat technologies.

As shown to the right, **four drivers are considered critical for gaining market leadership** and these have been the focus of this analysis and serve as a structure for recommending focus areas on the following page.

In addition to the drivers, **the development of the Scottish industry for low-carbon heat technologies relies on the collaboration and collective action between key actors** among policy-makers, network and industry organisation, universities and companies.

**Primary drivers for developing the Scottish digital heat tech industry**

| | |
|---|---|
| Regulations, Policies & Incentives | The supportive public policies, regulations, and funding schemes to drive the digital transition in heat |
| Industry Capabilities & Structure | Strong local industry and network organisations to support innovation, collaboration, and competition |
| Demand for Technology | Demand for advanced products and services within digital heat tech is key in driving the market forward |
| Society & Infrastructure | Encompasses strong local infrastructure, research, and human capital supporting the development of digital heat technologies |

**Key actors**

- Policy-makers
- Network & Industry organisations
- Universities and R&D
- Companies

# The analysis has identified focus areas for moving forward the Scottish digital heat tech industry

| Key drivers | Present state |
|---|---|
| Regulations, Policies & Incentives | Ambitious decarbonisation goals and dedicated policies for heating technologies. Early-stage development of policy framework for low-carbon heating, with funding to incentivise demand but limited support for R&D and supplying companies. |
| Industry Capabilities & Structure | The industry is dominated by large international corporations, whereas Scottish technologies developing advanced solutions to heating are mostly SMEs. Despite having various network organisations and innovation centres, none are dedicated to digital technologies in heating. |
| Society & Infrastructure | Digital sector is developing but the existing infrastructure and lack of interoperability hinder the national uptake of digital systems for heating. Despite a strong engineering base, there is a gap in sector-specific interdisciplinary digital skills. |
| Demand for Technology | Increasing gas prices and a growing focus on emission education lead to an increased need to optimise heat. However, due to a lack of awareness and high investment costs, the demand is mostly driven by public regulations and funding. |

| # | Recommended focus areas | Key Actors |
|---|---|---|
| 1 | **Joint vision** between Scotland and the UK to align initiatives and ensure a united perspective of the system integration and decarbonisation plans | Policy-makers |
| 2 | **Centralised support** for councils and communities in the local development of digitalised low-carbon heating | Policy-makers, Network & Industry organisation |
| 3 | **Scottish SMEs** are provided with the necessary resources (funding, mentoring, innovation management etc.) for research and innovation to match the capabilities of larger companies | Policy-makers, Network & Industry organisation |
| 4 | **Dedicated task force** for digital technologies in low-carbon heating establishing cross-sectoral collaboration | Policy-makers, Network & Industry organisation |
| 5 | **International market analysis** investigating the market size for the 15 chosen technology types to pinpoint the biggest investment opportunities | Policy-makers |
| 6 | **Improved data availability** through 1) Legal framework and public-driven initiatives as well as 2) Industry collaboration on standardisation of technologies and 3) data sharing among different systems and technologies | Policy-makers, Companies |
| 7 | **Upskilling programs** for professionals in 1) the private sector and 2) cross-sector teaching at universities building skillsets in heat and tech | Universities and R&D, Companies |
| 8 | **Research institutes programs** dedicated to digital heat tech, combining disciplines within digital technologies and heating to target current gaps | Universities and R&D |
| 9 | **Education of consumers** promoting the advantages and possibilities brought by the installation of digital heat technology | Companies, Network & Industry organisation |

**Legend:** Policy-makers; Network & Industry organisation; Companies; Universities and R&D

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# The project aims to analyse Scotland’s opportunity to become a market leader in low carbon heat tech

## Background

Economic, social, and political factors are all contributing to expectations of the low-carbon economy seeing growth rates four times higher than the rest of the economy in the UK over the next decade.

As concluded in the previous report delivered for Scottish Enterprise: ‘Heat Pumps and Heat Networks Assemblies and Key Component Analysis’, the market for controls of both of these technologies offer high potential for Scottish companies to take advantage. This is in addition to other digital technologies that can contribute to the decarbonisation of heat in the UK.

One of the main barriers to the faster uptake of digital solutions for low-carbon has been identified as costs. The Scottish low-carbon heat industry could play a role in reducing these costs and thus accelerate the UK’s green transition, while also boosting the Scottish economy.

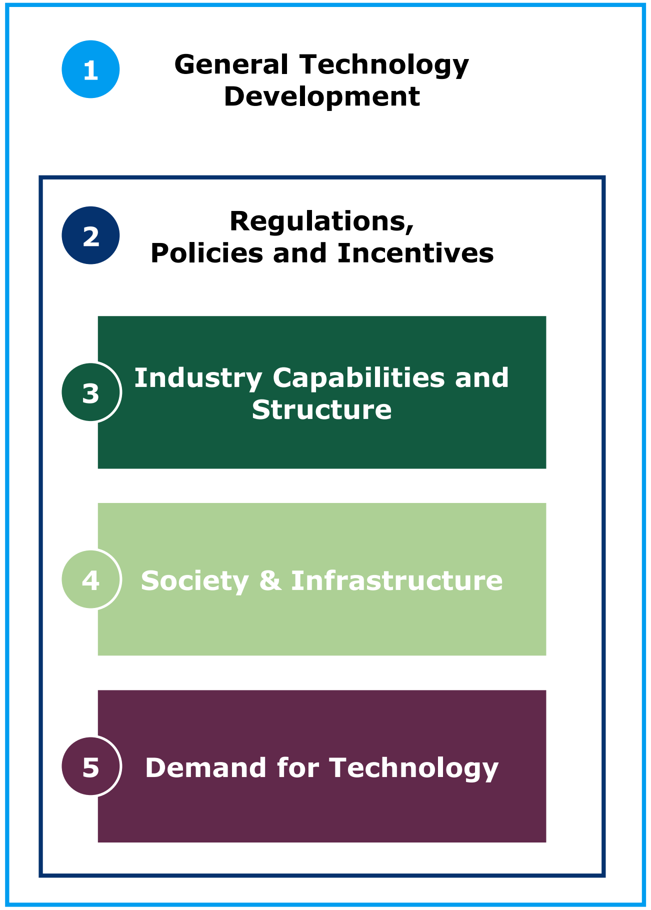
Scottish Enterprise seeks to understand the potential for Scotland to be a leader in the low-carbon heat tech industry, and would like recommendations for how to improve the competitiveness of the industry and firms within.

## Project approach

The project aims to **analyse Scotland's opportunity to become a market leader in low-carbon heat tech** and identify what steps could be taken to maximise this opportunity. This has been done through the following activities and analyses:

- **Identification and assessment of current technologies** used in the decarbonisation of heat, including an evaluation of where the technological trends are leading
- **Mapping and interviewing key stakeholders** from the Scottish digital heat sector across academia, companies and organisation to understand capabilities, opportunities and challenges for Scotland to become a market leader in low-carbon heat tech.
- **Assessment of Scotland’s national competitiveness** within the digital heat industry through analyses of policies, factors and demand as well as the industry structure and capabilities
- **Evaluation of the state of play in Denmark** with a focus on digital heat technologies to serve as learning and inspiration for Scotland’s transition
- **Summary of the key strengths, weaknesses, opportunities and threats (SWOT) for Scotland** to become a market leader within low-carbon heat tech, including recommendations on how to maximise this opportunity.

# A framework was developed to assess the factors & conditions required to enhance national competitiveness




**General Technology Development:** Technological development is a global phenomenon with different levels of adoption and maturity across countries and sectors. The development is driven by a combination of global megatrends and technological advancements of individual companies.

**Regulations, Policies and Incentives:** While regulations, policies, and incentives will never be the main driver behind market leadership, they will have a significant effect on how companies behave. By acting as catalysts and challengers, public authorities can push companies towards higher competitive performance. The overview of regulations, policies and funding showcases the state addressing the adoption barriers for technology for various private and commercial stakeholders.

**Industry Capabilities and Structure:** The characteristics of the local industry can have a significant influence on national competitiveness. The presence of network opportunities and local rivalry can help drive innovation which in turn could affect Scotland's ability to take a leading position within digital technologies for low carbon heat. The Scottish industry is analysed on a structural level and through an analysis of selected companies. The aim is to present the strengths and weaknesses as well as trends and opportunities for further development.

**Society & Infrastructure:** For the Scottish industry to become a world leader, necessary underlying conditions must be available in the country. This includes access to the necessary knowledge, showcased through academia mapping, the overview of human capital and necessary skillset, funding and incentive schemes available for the supply side, and an analysis of the infrastructure. Data availability, as the key infrastructure condition will be evaluated based on existing regulations and underlying issues such as cybersecurity and privacy concerns.

**Demand for Technology:** Having a large and advanced local market with sophisticated requirements will push companies towards innovation which will help create leading industries in a country. The demand side will be viewed from the perspective of opportunities and threats. The former is based on supportive regulation and funding driving demand as well as market drivers, whereas the latter considers the barriers to demand development. The barriers and challenges are subsequently addressed through the suggested new business models.

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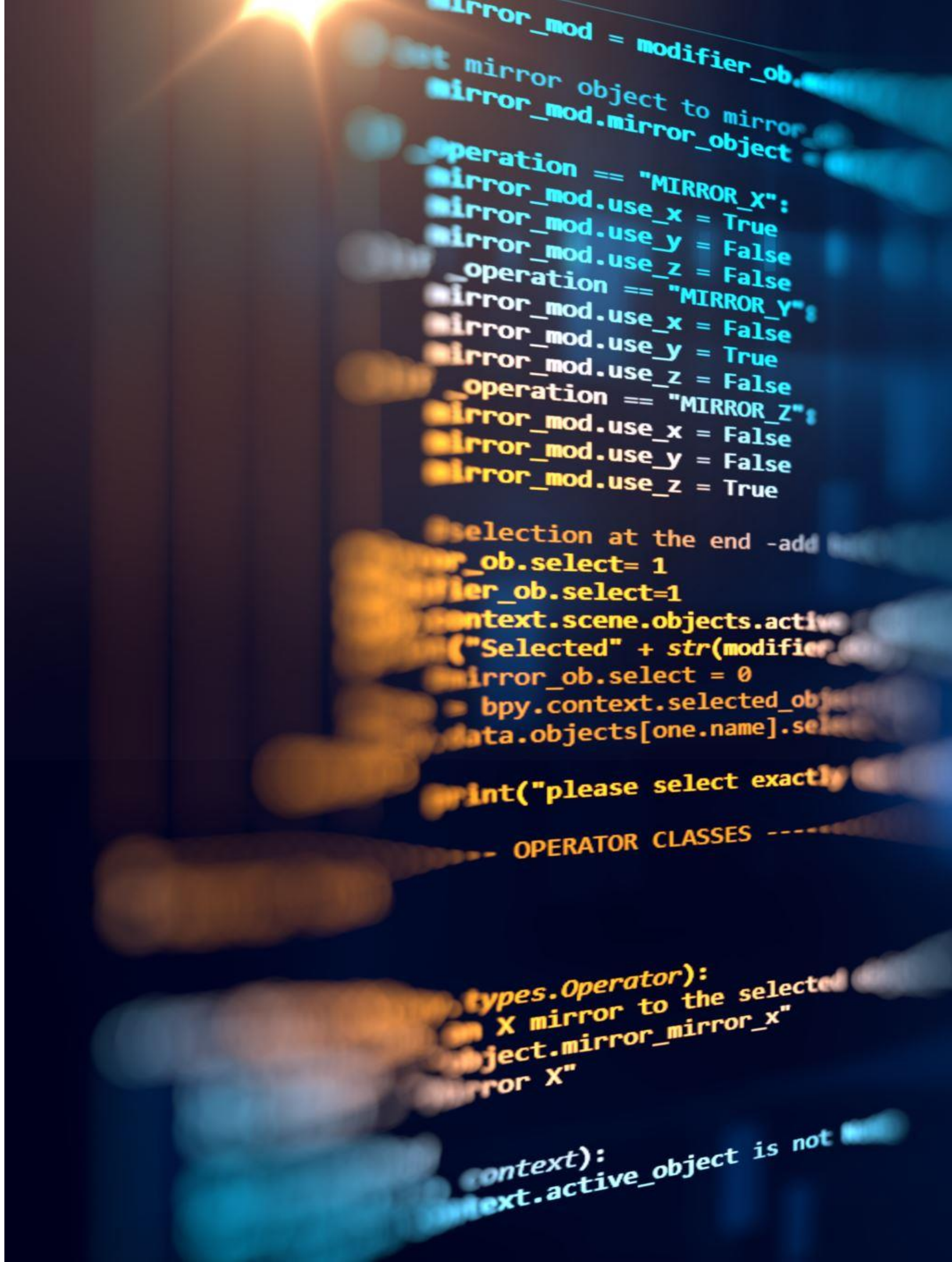


# What is Digital Technology ?

Digital technology consists of **electronic tools**, **systems**, and **devices** that **collect, generate, store, process, and share data.**

Digital technologies can be divided into the following key elements:

1. **Data/information collection/monitoring** — Input
2. **Data/information processing** — Processing
3. **Data/information sharing/display** — Output

**Storage**
Overlaps the three elements

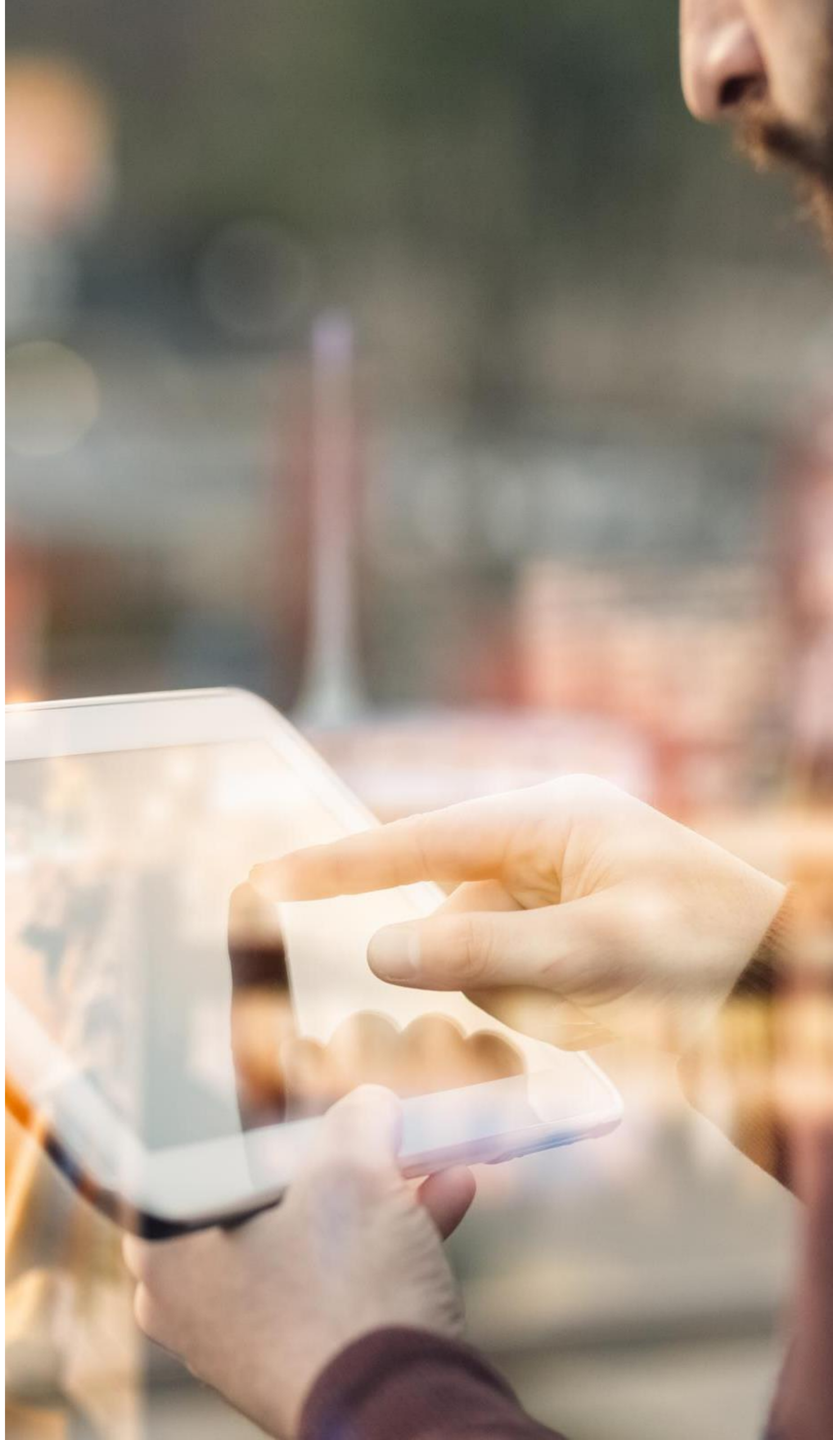
Each digital technology element requires **different tools, systems, or devices to perform its function**.

These elements can be further classified into:

- **Hardware** such as sensors and microprocessors
- **Software** such as apps and programs that control and operate the hardware

The **objectives** of digital technologies could be as simple as **recording several data points** and **processing** them to **present** them as a graph or using the recorded data points to predict or control the performance of a physical system.

The 15 technology categories identified as Input/Output or Processing are individually explored in **Appendix A**.



# Classification of Digital Technologies by Stages in a Heating System (I/III)

**Effective use of digital technology enables the optimised use of equipment in coordination with heat generation, distribution, delivery, and metering.**

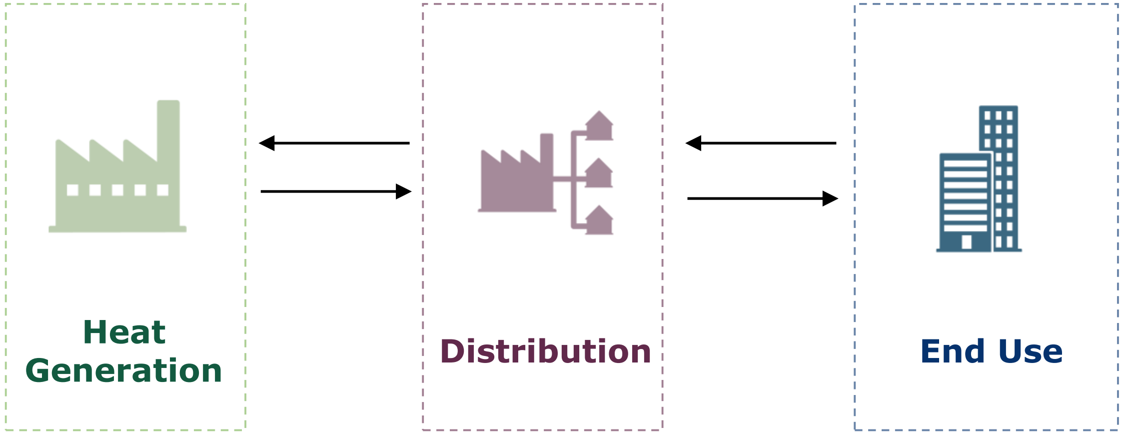
An end-to-end heating system consists of three primary stages:

- Heat generation
- Distribution
- End use

Digital technologies can be classified by their application in the above-mentioned stages (individually or in combination) within the heating system.

For example, a smart control system of a heat pump will fall under 'Heat Generation' and a smart thermostat will be under 'End Use', whereas a smart metering device like a flow, pressure, or temperature meter can be used for all three stages.

Whilst individual components of heating systems are vital to operation, the overall system performance and efficiency rely heavily on digitalised controls.




**Whilst individual components of heating systems are vital to operation, the overall system performance and efficiency rely heavily on digitalised controls.**

# Classification of Digital Technologies by Technology Type in the Context of Low Carbon Heat (II/III)

Digital technologies can also be classified by the type of technological application in the value chain as described below:

## Input | Output

This consists of **sensors** and devices that can **collect and share information**, work with the control unit of a heating system or independently, and performs specific actions instructed by a control unit or a user through an app or an interface.

As an example, a **smart thermostat** can sense, display, and share the surrounding temperature with (i) an **HVAC control unit** for performance optimisation or (ii) a **user** through an app/user interface who can set desired temperatures.

Some other examples of devices are **smart heat meters**, **flowmeters**, pressure sensors, occupancy and motion sensors, smart radiators, valves, heaters, and actuators.

These sensors or devices are designed either to be used in an individual stage of the heating system or across the whole heating system.

## Processes

Processes can be further divided into two sub-categories:

- **Design & Simulation:** This consists of software tools that are used to develop virtual models of physical systems.
- **Control & Optimisation:** Techniques such as adaptive learning, predictive simulation, AI, ML, etc. can be used to perform system control, self-monitoring, demand side response, remote diagnostics, and predictive maintenance of either an individual component in a heating system like a boiler, heat pump etc. or the whole heating system.

The devices and technologies under the **Input/Output and Processes** categories **can be used independently** where control at the system level is not required.

However, in a centralised heating system, they can be used **alongside each other to achieve the optimised performance of the whole heating system**. For example, a smart meter can either share data with the central control system to optimise performance or with the user only to observe the performance.

# The two classification methods combined constitute the framework for the Technology assessment (III/III)

**The chart on the right links the two introduced different classification methods by stages of heating system (I) and by technology type (II)**

**Examples of specific technologies are below each category.**

As stated before, they can either belong to one stage of the heating process or all of them.

Therefore, the technologies are not assigned to heating stages but rather based on the Input/Output or Processes.

| | Heat Generation | Distribution | End Use |
|---|---|---|---|
| Input / Output | • Remotely monitor and control performance (efficiency, heat generation, fuel consumption, operational hours, etc.) of generation equipment such as heaters and boilers.<br>• Share operating data with users and/or control units. | • Remotely monitor and control the heat distribution within the network by regulating flow rates, temperatures, operating hours etc.<br>• Record & share data such as heat demand variations in the network with users and/or control units. | • Smart devices measuring and sharing data on occupancy, set point temperatures, heat demand, flow rates etc.<br>• Smart actuators, heaters, and radiator valves are wirelessly operated to regulate surrounding conditions. |

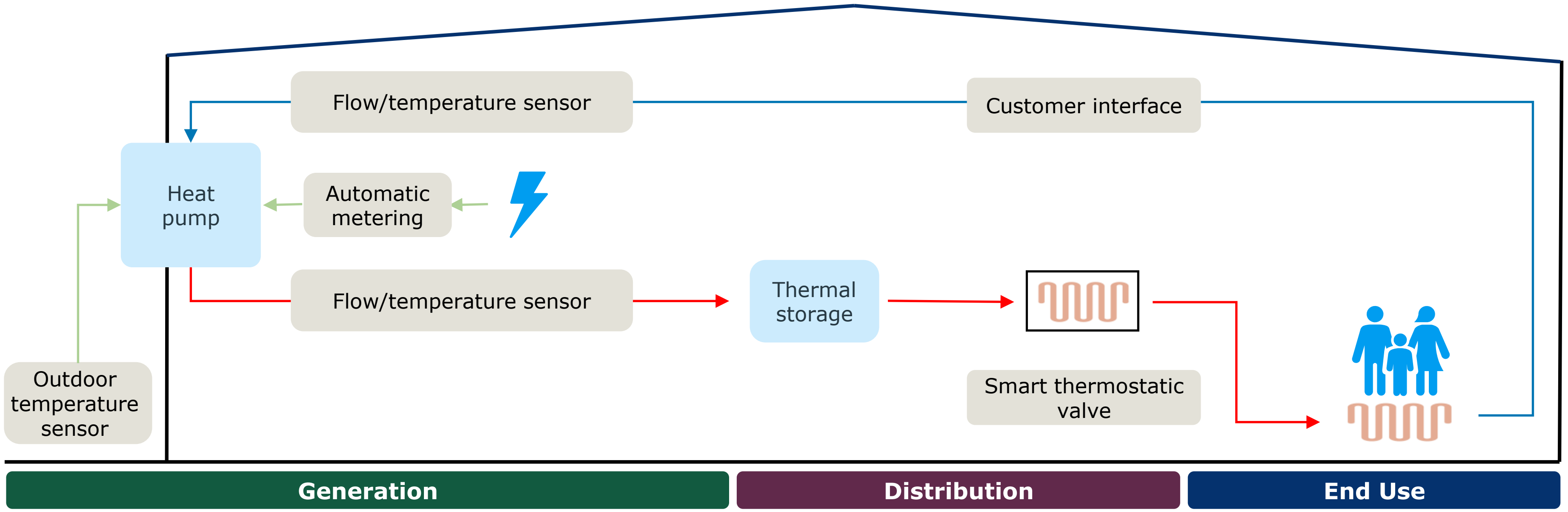
*Examples of technologies:* Smart Radiator Valves and Control; Wireless/online Data Analysis; Smart Thermostat; Customer Interface, Software & Apps; Smart Metering System; Sensors, Transducers, and Transmitters; Software and Apps; Smart Heaters/Boilers; Digital Actuators

| | Heat Generation | Distribution | End Use |
|---|---|---|---|
| Processes | • Remote control, self-monitoring, and diagnostic technologies for electric boilers and heat pumps 1) to improve performance and reliability 2) while supplying the demand at different rates.<br>• Developing simulation models of generation technologies. | • Network management and predictive learning tools and models can help in optimising heat distribution by 1) understanding the patterns in demand and 2)creating balance by communicating information with the rest of the system. | • BEMS integrates & controls the whole system on the basis of end-use data.<br>• The smart radiators and sensors feed data back to the main controller unit/tool and assist in adaptive learning of the whole system through predictive analysis.<br>• Radiators can be fitted with a remote monitoring system to detect early faults or compromised performances. |

*Examples of technologies:* Operation control & self monitoring; IoT, Big data, AI, ML; Smart Thermostat; Digital Twin; Remote monitoring and diagnostic; Heat Network Management Software; Smart HVAC; Adaptive learning & predictive simulation; Software & Apps; BEMS

# Digital Technologies implemented in the residential sector use simple processes to optimise heat consumption

- The **residential sector** can greatly benefit from the implementation of digital technologies in the local heating systems (i.e., heat pumps and thermal storage)
- The visualisation presents how new technologies such as sensors, meters, and smart valves are integrated into the residential heating system
- The outdoor sensor is an example of **external input** contribution affecting the internal grid. Other external information can be e.g., energy unit cost data or grid usage
- Automatic metering systems, as well as flow/temperature sensors and smart thermostats, contribute to the **efficiency analysis** as well as allowing setting temperature via customer interface and later **system performance analysis**

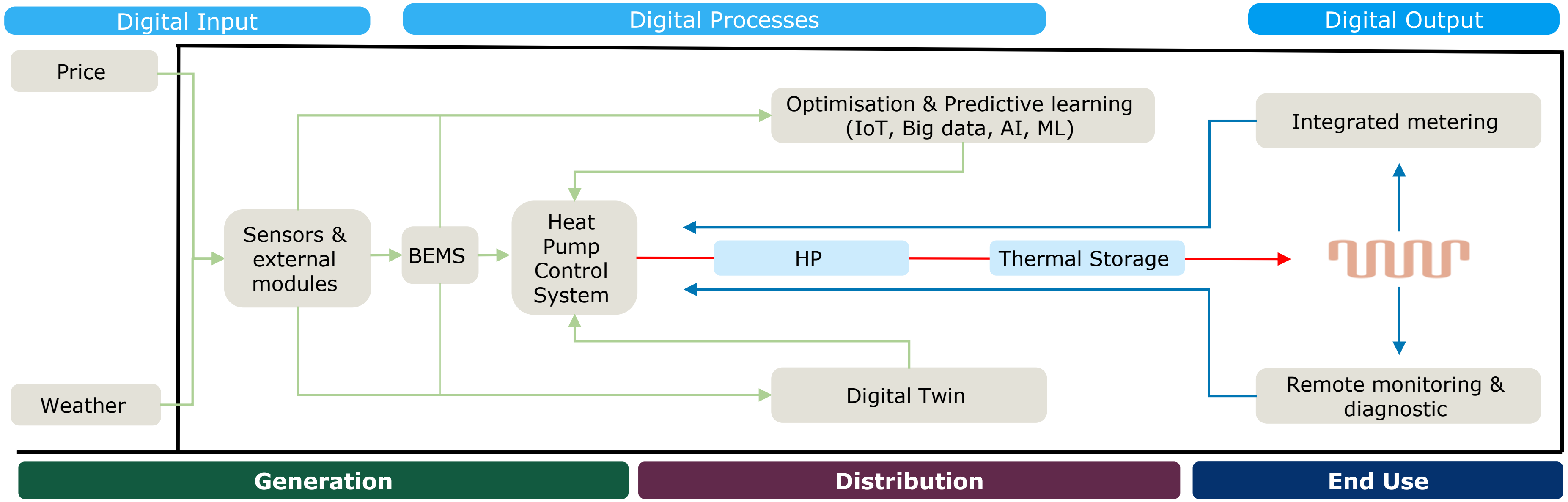



Based on the example it is apparent that digital technologies are greatly contributing to:

- **Reducing energy consumption and cost on an individual energy system level** (through optimised use of individual system components, effective use of the thermal store, and correct use of variable tariffs)
- **Ensuring thermal comfort and desired living conditions** (through advanced sensor use and data processing, incorporation of weather data to control system, and data monitoring to enable effective fabric interventions)
- **Operating energy system to optimise energy use in the context of a wider energy network** (lower energy unit costs in times of energy surplus that can be used with a thermal store to reduce annual fuel costs and reduce pressure on the national grid by altering energy demand behaviour)

# Current digital technologies in use in the non-residential sector are aimed at developing system integration

- This graph focuses on possible technological applications in existing and new **commercial and office buildings**.
- Digital technologies in the **industrial sector** operate on the same premises but are usually more complex and customized.
- **Digital inputs** are where external data is integrated into the system through sensors, external modules, and smart metering.
- **Digital processing products** like Digital Twin or BEMS integrate present, historic, and forecast data to optimise energy production, and maximise the lifespan.
- **Digital output** through customer interfaces such as apps, dashboards, and displays allows remote control data sharing and smart metering.




The framework visualises the high complexity in the non-residential settings and its contribution to:

- **Reducing energy consumption and cost on an individual energy system level** (through optimised use of individual system components, effective use of the thermal store, and correct use of variable tariffs)
- **System optimisation and smart learning** (through the IoT, Big data, AI, ML, Digital Twins or Smart HVAC/BEMS which provide integration of external and internal data to learn about possible improvements and detection of faults and problem areas as well as allow complex remote control)
- **Flexibility and grid integration** (the building stock can respond to the power grid and store or sell the energy depending on the power generation through sensors, transmitters, and external modules)

# Scotland focuses on data gathering with the aim to allow heating optimisation and future power grid integration

Primary technology phase for Scotland

| | 1 Data Gathering | 2 External integration and self-optimisation | 3 Whole system integration |
|---|---|---|---|
| **Trends** | The predominant application of digital technology mainly focuses on gathering data. This includes smart thermostats, the use of humidity sensors, and data logging (via smart meters, etc).<br><br>This enables **increased optimisation** of heating for thermal comfort and a **better understanding of building stock** for future retrofit and national policy planning. | The focus for the near future will include **interconnectivity** to **external systems** including weather data, variable cost tariffs, and available grid capacity. Control systems themselves will also increase in capability to **minimise poor performance**.<br><br>This enables the more **advanced operation to optimise the cost of heating and help balance the national grid** as it increases its reliance on non-uniform energy generation that varies with weather or time of day. | Digital technology aims to **connect the individual elements of a heating system together** while optimising operation.<br><br>This will bring many technologies together to achieve the aim of digital technology in **net zero heating systems**. Consumers will be central to this system, becoming active participants in the energy market, buying and selling the energy generated from low-carbon technologies from their homes and using smart controls to shift demand to periods when the prices are lower. |
| **Technologies Involved** | • Sensors<br>• Smart/Integrated Metering<br>• Smart thermostat<br>• Adaptive Electrical Charging Devices<br>• Heat Network management software<br>• System components - Smart controls for thermostatic radiator valves and electric heating | • External Systems (look at weather data, variable cost tariffs & grid capacity)<br>• System components - Smart controls for thermostatic radiator valves and electric heating | • City-wide digital twins/energy modelling<br>• Peer-to-peer trading from renewable energy sources attached to homes (e.g. solar panels) |
| **Scotland** | Scotland is currently in the phase of data gathering from residential digital devices that apply to both gas heating and newer low-carbon energy systems. Due to supportive regulation, there is an upcoming smart meter adoption in the UK as well as development of methods of data sharing. | With the rising prices of gas and electricity, the residential and non-residential sectors are looking into ways of reducing costs, increasing control over the internal systems as well as reducing carbon emissions. | The gas and electricity networks already complement one another when it comes to the production of electricity using gas. Open data and digital technologies are recognised tools for grid optimisation, especially when it comes to plans to increase the generation of renewable power. |

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# The policy pathway established a timeline to zero-carbon heat and drives the uptake for digital technology in Scotland

**The following timeline of regulations being implemented in Scotland aims at zero carbon heat by 2045.**

It jointly will have a considerable impact on the growth and development of the digital technology sector.

All companies interviewed for this research agreed that they were in a good position to take advantage of the growing low-carbon sector and all cited regulations as important drivers for stimulating demand where it is not necessarily consumer-led, due to a lack of interaction between individuals and their heating systems.

These policy frameworks will stimulate demand as digital products will be required to decarbonise and electrify heat and will be further addressed in the coming sections.

**2014**
Energy Efficiency Standard for Social Housing (EESSH)
- Setting 3 milestones in 2014, 2025 and 2032 in terms of minimal EPC rating for social housing

**2018**
Climate Change Plan 2018 to 2032 (Updated in 2020)
- Buildings to be near net zero by 2050
- 35% of residential and 79% of non-residential buildings' heat to be supplied using low carbon technologies by 2032
- Energy Efficiency Standard for Social Housing

**2020**
Smart Meter Policy Framework
- The UK Government wants energy companies to provide smart meters to every home in England, Wales, and Scotland by mid-2025

**2020**
Heat in Buildings Strategy
- £1.8bn investment plan
- Reforming EPC Ratings
- 1 million residential properties & 50,000 non-residential properties using gas converted to zero-emission heating by 2030
- Homes to have at least a band C EPC rating by 2033

**2021**
Heat Networks Scotland Act
- Makes heat networks attractive for investors through business relief rates, securing demand and zoning

**2021-2023**
Local Heat and Energy Efficiency Strategies (LHEES)
- Long-term plan for decarbonising heat and improving energy efficiency across local authority areas
- Every Local Authority to have an LHEES by the end of 2023

**Now**

**2024**
New Building Heat Standard
- New buildings must install only zero direct emission heat sources

# Regulations should incentivise electricity over gas usage in the long-term and communicate a clear vision

## Signalling change

Energy policy costs to support renewable asset deployment and targeted social measures are currently recovered through consumer energy bills. **The highest taxes by a significant amount are on electricity usage.**

For a long period of time, there were **no gas-specific policy costs** placed on consumer bills, with all policy costs relating to either electricity-only schemes (e.g., the support of renewable electricity generators) or dual fuel considerations (i.e., addressing fuel poverty through the Warm Home Discount).

The **Green Gas Levy (GGL)** has changed this, but taxes have remained significantly higher on electricity consumption compared to gas before the crisis. The result is that despite the huge efficiencies of around 300% or 400% offered by different heat pump technologies, compared to around 85% for a gas boiler, switching directly from a fossil gas heat source to a heat pump could still be a more costly option for consumers.

**The current crisis has reduced the price disparity**, which has improved the economics of using low-carbon heat technologies. However, this could change again. Measures are therefore still necessary in the longer term to maintain the closer relationship between electricity and gas prices

Although a dynamic or time-of-use electricity tariff improves the economics of low-carbon heat technologies, a much cheaper energy alternative (gas) stands in the way of investments in low-carbon heat technologies and complementing digital technology.

| **Overall tax on residential energy use in the UK (%)** | Gas | Biomass | Electricity | Oil |
|---|---|---|---|---|
| | 5 | 5 | 22 | 24 |

## Establishing a clear vision moving forward

Clear communication about the envisioned future heating systems in Scotland is needed for companies to invest in complementary digital technologies.
So far, there has been no clear messaging to either the consumer or the private sector about the digital technologies they should adopt (e.g., when making use of governmental incentives for switching to low-carbon heat)

Concerning low-carbon heating options, **two main visions co-exist in the UK**, supported by different actor groups:

1. Emerging actor coalitions[1] support the deployment of low-carbon substitutes
2. Established coalitions[2] favour preserving pathways (e.g., efficiency improvements, appliance replacements, and greening of the gas grid).

The visions have changed multiple times from electrification to heat networks, to repurposing the existing gas infrastructure. While the solution is going to be multi-faceted**, it needs policy coherence over time.**

In Sweden and Switzerland, early government support for heat pumps was introduced in the 1970s, but it was not until the 2000s that a major market increase was seen, showing the **need for long-term and continuous support** for energy technology innovation.

Notes: [1] Inter alia early adopters, NGOs, new housebuilding actors; [2] Inter alia the gas industry, the concentrated housebuilding industry against tighter building standards, an effective lobby against a shift towards low-carbon building codes to keep costs down & reduce regulatory burdens

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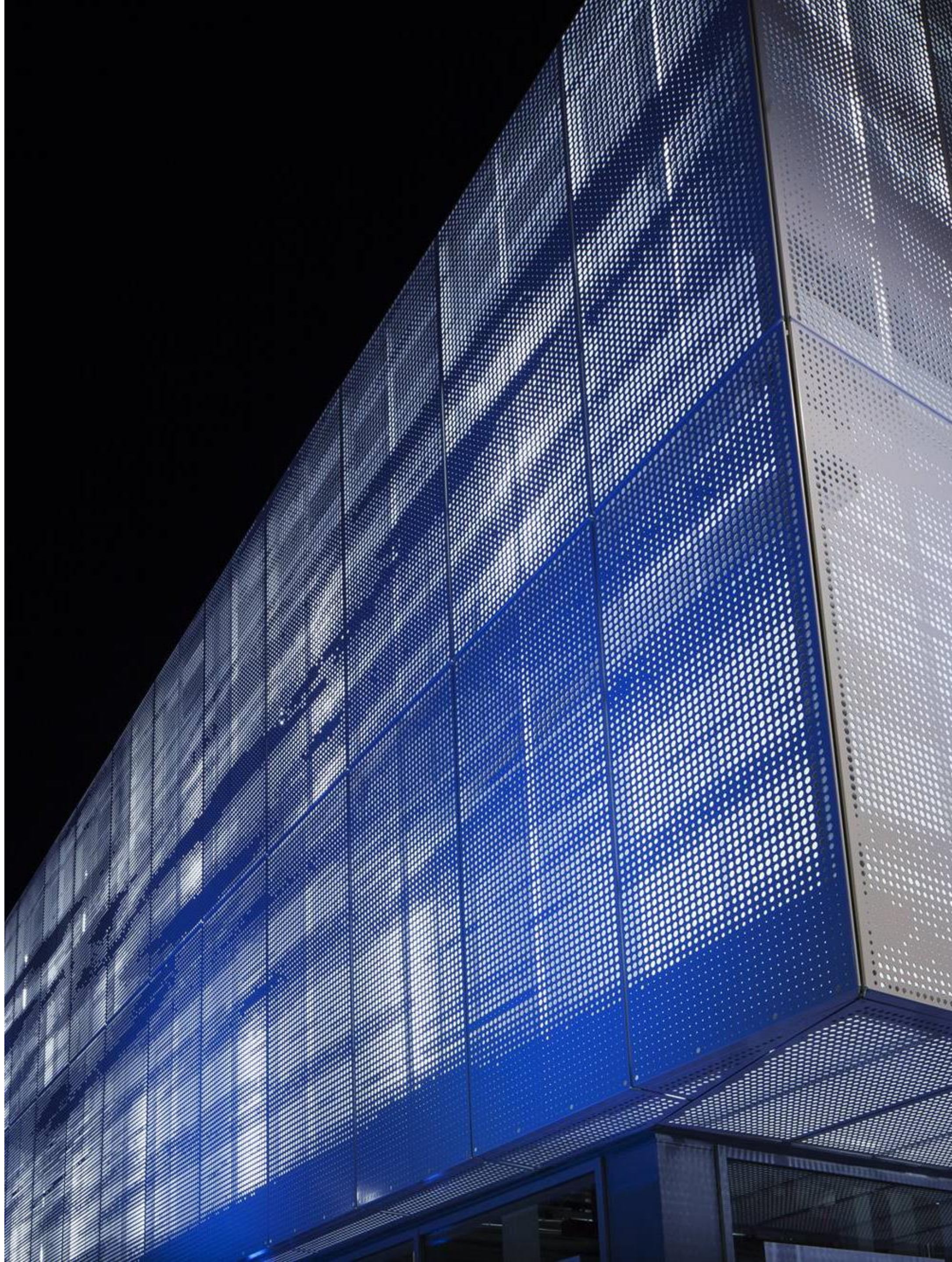


# 47 stakeholders have been identified that are relevant to the low-carbon heat digital technology

**Data collection methodology**

- **60 Stakeholders were initially identified from the Industry and Academia**, mostly from Scotland. This list was reduced to 47 to include closely relevant stakeholders only.
- A target of 12 stakeholder interviews was set for the project.
- Due to the high number of stakeholders identified, two lists of stakeholders (primary and secondary) were created, with 12 stakeholders in each list, for prioritizing the stakeholders for the interviews.
- **SE's preferences were considered for creating the stakeholder priority lists.** SE identified 27 Stakeholders as 'Essential' or 'high priority for interviews'.
- **12 stakeholder interviews were completed in the UK,** complemented with **4 expert interviews** on digital, heat networks, and district heating technologies.
- The 12 external stakeholders from the UK include NESTA, Warmworks, Star Renewable Energy, CENSIS, BE-ST, Integrated Environmental Solutions (IES), Hysopt, Thermafy, Delta-EE, PNDC, SAV Systems, and Heriot-Watt University.

**47**
Identified stakeholders

**27**
"Essential" or "high-priority for the interview" companies

**12**
Interviewed organisations

**4**
Expert interviews

**Analysis structure**

- The key takeaways are included in mapping the industry structure and capabilities, where detailed information on all 47 stakeholders is included in the Excel database.
- The company mapping is developed in a way that aligns with the technologies represented in the project, therefore, the companies are structured depending on whether they primarily focus on **Input, Output, or Processing digital technologies.**

Input Technologies
Output Technologies
Process Technologies

- Moreover, the company mapping is complemented with slides on both the industry **maturity** and the collective **capabilities** of the stakeholders.
- The **network opportunities** and collaboration between different stakeholders in the industry are explored through the analysis of different partnerships, associations, and research programs.
- The section concludes with **the growth opportunities**, which have been conceptualised based on desk research and validated through interviews with industry experts.

# Company Mapping for Input/Output Technologies

HQ in Scotland HQ Elsewhere

| Company | Sensor and Transmitter | Smart Metering System | Smart Thermostat | Customer Interface, Software and Apps | Wireless/Online data analysis | Smart Radiator valves and Control | Smart Heaters, Boilers, HP and Storage | Digital Actuators |
|---|---|---|---|---|---|---|---|---|
| Danfoss | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Resideo | | | ✓ | ✓ | ✓ | | | |
| Mitsubishi Electric | | ✓ | | ✓ | ✓ | | ✓ | |
| West Coast Controls | | | | | ✓ | | | |
| Likido Energy Scotland | | ✓ | | ✓ | ✓ | | | |
| Electric Heating Company | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| J-Teq Energy Ltd | | | | | ✓ | | | |
| Tantallon Systems Ltd | | | | ✓ | ✓ | | | |
| Vital Energi Scotland | | ✓ | | ✓ | ✓ | | ✓ | |
| Star Renewable Energy | | | | ✓ | ✓ | | ✓ | |
| Boxergy | | | | ✓ | ✓ | | | |
| CC North Ltd | | | | ✓ | ✓ | | | |
| Logic Energy | | | | ✓ | ✓ | | | |
| ThermaFY | | | | ✓ | ✓ | | | |
| Arbn Co. | | | | ✓ | ✓ | | | |
| Flexel | | | | | | | ✓ | |
| Sunamp | | | | | | | ✓ | |
| Snugg Energy | | | | ✓ | ✓ | | | |
| Novoville | | | | | ✓ | | | |
| Urban Tide | | | | ✓ | ✓ | | | |
| Meter Tech | | ✓ | | | | | | |
| Smart Metering Solutions | | ✓ | | | | | | |
| Energy Assets | ✓ | ✓ | | | ✓ | | | |
| Connected Response | ✓ | | | ✓ | ✓ | | | |

# Company Mapping for Process Technologies

HQ in Scotland    HQ Elsewhere

| Company | Control & Monitoring | Remote Diagnostic | Adaptive learning & Predictive Simulation | BEMS | Heat Network Management | IoT, Big data, AI and ML | Smart HVAC |
|---|---|---|---|---|---|---|---|
| Danfoss | ✓ | | | | | | ✓ |
| Resideo | ✓ | | | | | | ✓ |
| Mitsubishi Electric | ✓ | | | | | | ✓ |
| West Coast Controls | | | | ✓ | | | ✓ |
| Likido Energy Scotland | ✓ | | | | | | ✓ |
| Electric Heating Company | ✓ | | | | | | |
| J-Teq Energy Ltd | ✓ | | | | | | |
| Tantallon Systems | ✓ | | | | | | |
| Vital Energi Scotland | ✓ | | | | ✓ | | |
| Star Renewable Energy | | | | | | | |
| SAV Systems | | | | | ✓ | | |
| CC North Ltd | | | | ✓ | | | |
| Logic Energy | | | | | | ✓ | |
| ThermaFY | | | | ✓ | | | |
| IES Ltd | | | | ✓ | | | |
| CENSIS | | | | | | ✓ | |
| Nomad Energy Solutions | | | | ✓ | | ✓ | |
| Allo Energy | | | | | | ✓ | |
| Craigalan Control Systems | | | | ✓ | | | |
| Hysopt | | | | ✓ | | | |
| Flexitricity Ltd | | | ✓ | | | | |
| Sweco | | | | | ✓ | | |
| Novoville | | | | | | ✓ | |
| Urban Tide | | | | | | ✓ | |
| Key Facilities Management | ✓ | ✓ | | | | ✓ | |
| Energy Assets | ✓ | | | | ✓ | | |
| Connected Response | ✓ | | | | | | |

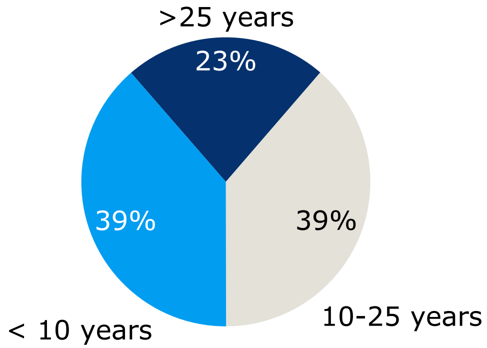
# The industry is developing, with most Scottish companies in the digital sector are young SMEs

Aside from the technological capabilities, it is relevant to characterise the stakeholders in the Scottish industry also by their age, size, and location. Therefore, their characteristics are used as a collective visualization of the present state of the industry.

- The industry of digital tech related to low-carbon heating in Scotland is a **growing and young sector**, predominantly **dominated by small and medium-sized players** based in Scotland.
- **The is no large company (>200 employees) that is headquartered in Scotland**, and the market is highly influenced by the more established international companies with decades of development like Danfoss or Mitsubishi. Even though those companies contribute greatly to the economy with a wide range of products and services, sometimes even manufacturing domestically, they are not representative of the state of Scottish industry. Where most Scottish SMEs are targeting local markets, foreign companies have an international presence.
- The **maturity of the companies corresponds to the development of digital technologies**. Notably, a lot of important players, especially providers of software solutions, like Nomad Energy Solutions and Warmworks, began operations less than seven years ago.

## Maturity

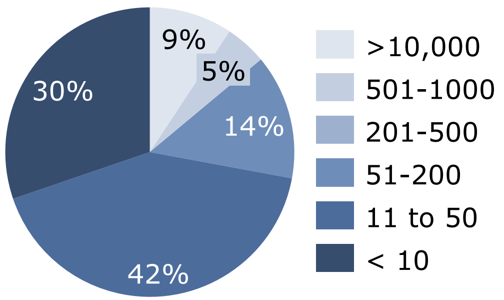
The maturity of the industry is determined based on the founding year of the investigated companies.




Most of the entities are relatively young with a median founding time in 2011, whereas the youngest software companies began operations only in 2022. The majority of enterprises are less than 25 years old and the distribution between more mature and younger companies is even.

## Size

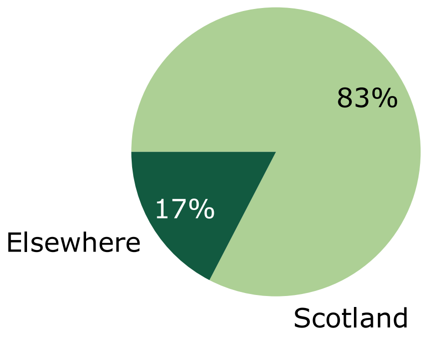
The company size is linked with its age, where the more mature the company the higher the number of employees.




Established companies with decades of development like Danfoss or Mitsubishi reached more than 10,000 employees globally. The majority of the industry (86%) is categorized as SMEs with the number of employees ranging from 2 to 200.

## Location

The industry consists of companies present in the sector, with headquarters located in Scotland and elsewhere.




The majority of investigated entities (83%) have headquarters in Scottish cities, predominantly Edinburgh and Glasgow. The primary location of the larger international companies is out of Scotland, whereas the SMEs are of national origin.

*The percentages are based on the number of companies being part of the assessments

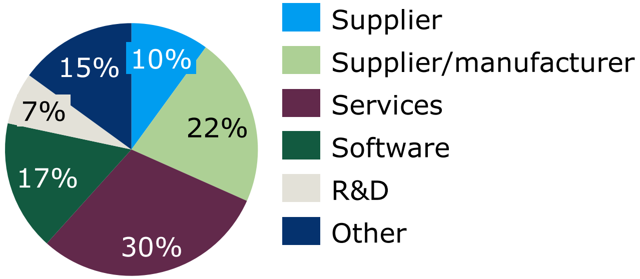
# Scottish stakeholders represent different roles in the industry and target both residential and industrial sectors

The Scottish industry for digital technologies developed to support low-carbon heating consists of companies offering products and services (hardware, software, or a combination of both) and support organisations that conduct research, offer consultation or incubate the newest tech start-ups.

- Out of the 15 technologies, identified for the scope of the project, 14 are addressed at least by one company, where the only **missing product in the market are remote diagnostics.**
- The majority of companies are involved in the development of **more than one type of digital technology**. For example, Danfoss covers 9 out of 15, followed by Electric Heating Company at 7.
- With the variety of stakeholders representing different roles in the value chain, the **representation of Scottish capabilities is satisfactory**. Especially the supportive organisations helping with consulting and business development allow further industry development.
- The application of advanced technologies such as **IoT, Big Data, AI, and ML** for low carbon heat is also at a very **early stage** and is mainly developed by **SMEs**, where companies with more available resources are not actively pursuing them.

## Primary activity

Companies in Scotland are characterized based on their core activity and predominant role in the industry.




The **suppliers and manufacturers** are directly linked to hardware, and they engage in either or both and have the biggest presence (32%) in the industry.

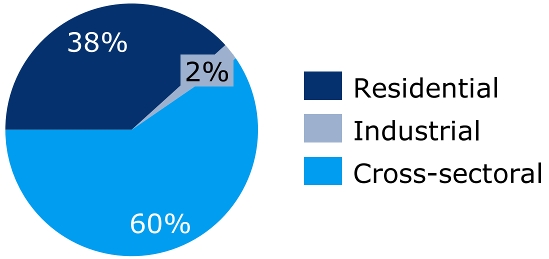
**Services and software** companies are also nearly equally represented (47%), where they often jointly offer services, software, and consultancy.

**R&D** (7%) is defined as academic activities developing the chosen technologies and are linked to Scottish universities or their adjacent research centers.

**Other** companies (15%) represent supportive roles such as innovation centers, installers, and associations.

## Target market

The technology is either for residential or industrial applications, where some offer cross-sectoral solutions.




The companies focus predominantly on the **residential sector** (38%), which also corresponds to the current market trends influenced by recent policies. Most of the producers offer control & monitoring systems, BEMS, and Smart HVAC.

The **industrial sector** (2%) requires more complex technologies, tailored to the optimisation of multiple processes, which is addressed by companies developing solutions based on IoT, Big Data, AI, and Digital Twins.

**Cross-sectoral** (60%) represents companies with multiple product offerings, the large corporations developing multiple products at once.

*The percentages are based on the number of companies being part of the assessments

# Scotland has strong innovation centres but lacking a clear focus on heat tech

- Scotland has **strong innovation centres** across all needed areas of expertise for digitalising heat: Innovation Centre for Construction (BE-ST), Sensing & IoT (CENSIS), and Data & AI (Data Lab). These Innovation Centres connect universities with sector-specific groups and themselves.
- **Within the sector-specific groups** [i.e. (renewable) energy, heat network, building sector], **the ambitions need to be combined** to achieve a low-carbon heating transition and digitalisation
  - Too many groups with similar ambitions exist, which demonstrates lacking collaboration.
  - All these groups are interested in efficient, low-carbon heating as part of their portfolio of interests, but not solely in the topic.
  - Since there was no targeted interest group for low-carbon heating **HeatSource** was created, delivered by BE-ST, and supported by Scottish Enterprise.
- The crucial challenge is the **missing link between low-carbon energy and digital technology**, as there is no organisation that brings together the stakeholders from those two groups, especially that is aimed at increased collaboration between private organisations.

**Digital innovation centers**

**BE-ST**
Provides connections, infrastructure, and culture needed to solve the construction sector's most pressing challenges.

**CENSIS**
Scotland's Innovation Centre for sensing, imaging, and Internet of Things (IoT) technologies.

**Innovate UK**
UK's national innovation agency, supporting business-led innovation in all sectors, technologies and UK regions.

**The Data Lab**
Scotland's innovation centre for data and AI with a network of over 1,500 companies, public sector organisations and universities.

**Transformation of building stock**

**UKGBC Scotland**
Launched a new network dedicated to accelerating the transformation of the built environment.

**The Existing Homes Alliance**
Coalition of housing, environmental, fuel poverty, consumer, and industry aimed at retrofitting the housing stock.

**Zero-carbon society**

**The Heat Network Support Unit**
Collaboration of agencies focused on the promotion and support of District Heating schemes in Scotland.

**HeatSource**
Collaborative knowledge hub exploring opportunities in low carbon heat; bringing together knowledge, partners, and resources.

**Scottish Renewables**
Trade body for Scotland's renewable energy industry lobbying for the growth of the sector.

**Education and empowering private consumers**

**Energy Action Scotland (EAS)**
Campaigns for an end to fuel poverty in Scotland and is the only national charity with this sole remit.

**Energy Saving Trust UK**
Provides leadership and expertise to companies, consumers, and public organisations to deliver a "zero carbon society".

# The growth opportunities lie in advanced technologies, support for Scottish companies, and increased interoperability

**Overall, the representation of companies providing digital technologies in Scotland is satisfactory and serves as a strong fundament for the future development. However, to be able to compete internationally the following growth opportunities have to be explored:**

## 1 Focus on advanced technologies

- The global industry trend is the adaptation of advanced technologies such as AI, IoT, Big Data, and ML in the sector.
- Only Scottish SMEs are currently offering advanced process technologies, and no large domestic company is active in this sector.
- There are no players developing tools for remote diagnostics, which is important to further optimise and improve the performance of the heating systems.
- There is a need for larger organisations with more resources to invest in further development of the market.

## 2 Developing Scottish organisations

- Building the capabilities in Scotland relies on the internal market and the international positioning of domestic corporations.
- The industry currently is dominated by large international players with no direct focus on developing the Scottish economy.
- The key to growth is strengthening the Scottish companies and providing them with financial resources, and consulting, especially the innovative software providers.

## 3 Increased interoperability

- Scotland has built a strong base for hardware and a variety of software services are rapidly developing, nevertheless, the biggest future challenge is their interoperability.
- This requires also legal structures allowing for the data collection and sharing between separate private entities and private customers.
- **The biggest potential for growth is focused on software and techniques enhancing the connectivity between different systems that can further contribute to the whole grid integration.**

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# There are four fundamental conditions for the development of the industry for low-carbon heating digital technology

## Research & Development

- Universities and research centers serve an important supporting role.
- Especially for digital technology, universities are often the origin of new business models or technological innovation.
- Universities through dedicated study programs are also developing the necessary skillsets.

**Key takeaways**:
Universities have reputable engineering schools, with upskilling programs and research centers dedicated to innovation and are establishing private-public digital clusters.

## Human resources

- Low carbon heat technologies are more complex in terms of installation and maintenance.
- There is a need for both the installers to maintain the physical appliances and engineers developing the associated software.
- The critical missing component is the digital skills combined with knowledge of the heating tech.

**Key takeaways**:
There is not enough skilled labour on both the engineering and installing levels, for which the demand is much higher than the present available supply.

## Financial resources

- The capital investment for the installation is higher than for the established gas boilers.
- State funds are targeting both the demand and supply sides. The intention is to lower the initial investment cost for the buyers and increase the R&D and capital grants both for researchers and entrepreneurs.

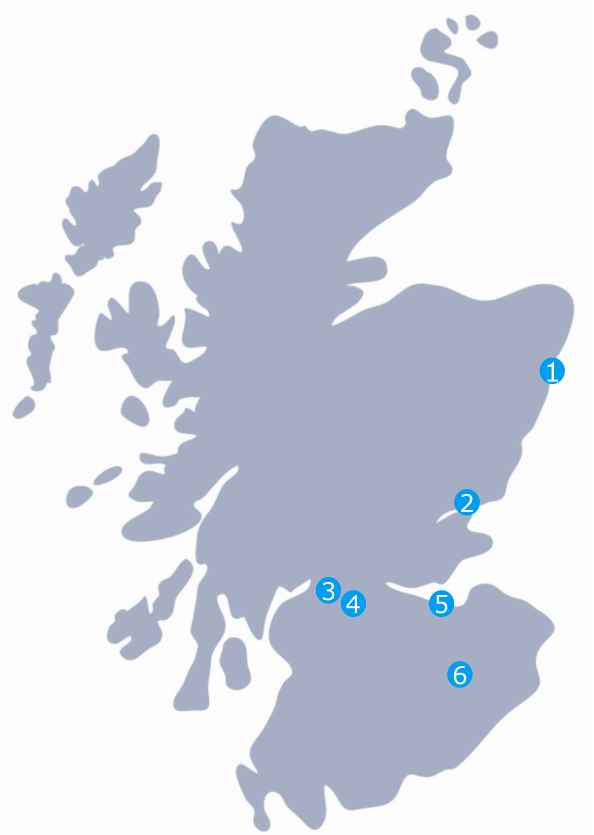
**Key takeaways**:
Public funding schemes are predominantly focused on the demand side, whereas not enough support is given to the supply side, for both upskilling and businesses.

## Infrastructure

- The fundamental infrastructure condition is the availability of data.
- Regulations influence data availability as well as state-imposed technological standards and privacy concerns.
- Private investment and the industry standardisation level are also relevant for future development.

**Key takeaways**:
The digital technology infrastructure is sufficient, but there is potential to further utilise it in the sector. Data availability and lack of standardisation constitute an important barrier.

# Scotland has well-established engineering schools with the right programs to establish skillset in digital tech




Scotland has multiple **highly-ranked** universities, which offer multiple **engineering degrees** at both undergraduate and postgraduate levels that have established **research centers** relevant to digital technology development and innovation.

| Academic institution | Students | Teaching degrees | Research |
|---|---|---|---|
| 1 **University of Aberdeen** | ~ 14k | 4 MEng & 2 BEng Engineering | Dedicated HVDC Research Centre and a developed research task force in internet engineering |
| 2 **University of Dundee** | ~ 16k | 2 MEng & 5 BEng Engineering | Strong software engineering & focus on turning innovative technologies into businesses through an entrepreneurship support system |
| 3 **University of Glasgow** | ~ 35k | 18 MEng & 19 BEng Engineering | Highly ranked in both Scotland and internationally with 96% of research judged "world-leading"[2] with acclaimed civil engineering research centers |
| 4 **University of Strathclyde** | ~ 23k | 10 MEng & 9 BEng Engineering | Top university for mechanical engineering, collaborating with the industry and research unit on built environment energy utilisation and optimisation |
| 5 **University of Edinburgh** | ~ 49 k | 9 MEng & 10 BEng Engineering | Ranked 1st in Scotland and 3rd in the UK for the quality and breadth of our engineering research[2], highly ranked for computer science |
| 6 **Heriot-Watt University** | ~ 20 k | 7 MSc & 4 BEng Engineering | Ranked 1st in Scotland and 3rd in the UK for the quality and breadth of our engineering research[2] |

Scottish engineering schools are providing the skills needed for software development, but the **missing link is providing students with specific courses on low-carbon heating technologies.**

Notes: [1] Position in global general engineering ranking based on Times Higher Education (2023); [2] Joint research award for H-W and UoE in Research Excellence Framework 2021

# The R&D sector for digital technologies is growing, with many universities focusing on low-carbon tech

Digital Technology is **one of the fastest growing sectors in Scotland** with over 1500 companies employing around 100,000 people contributing 3.5% of total GVA to Scotland's economy in 2019. The sector is growing 1.5 times faster than the overall economy and is expected to be 26% GVA by 2029.

The Scottish academic R&D dedicated to that industry is divided into three clusters: **Aberdeen, Glasgow, and Edinburgh.**

Scotland has built a strong technological industry with both companies and an R&D base and the two clusters, **Edinburgh and Glasgow, have been in the top five most active tech communities** outside London in the UK.

| Area | Relevant Research Activity |
|---|---|
| Aberdeen Cluster | • The **Centre for Energy Transition** at the **University of Aberdeen** is working on the development of intelligent systems to monitor and analyse energy generation, distribution, and demand data. |
| Edinburgh Cluster | • **University of Edinburgh** has been collaborating with **Hysopt** to develop Digital Twin technologies for HVAC systems. |
| Glasgow Cluster | • The **University of Glasgow** and **IES** started a partnership in 2019 to develop the Digital Twin of the university's western campus and the district heating system.<br>• The **PNDC**, part of the **University of Strathclyde**, founded in 2013 is an established innovation center that offers whole energy systems research, test, and demonstration environment. Their thermal innovation facility has been used to test and demonstrate low-carbon thermal technologies, systems, and digital solutions. |
| Dundee Cluster | • **Digital Dundee** is a cross-sector collaboration between academia, industry and the public sector to support and promote growth in the digital technology sector and related applications. |

Scottish universities play an important part in industry development and their primary focus to date has been on developing low-carbon heat technologies. Nevertheless, the associated digital tech and their deployment have not been widely researched. **There is a need to develop dedicated R&D centres to accelerate the university's contribution to the sector and to combine R&D capabilities through collaboration between existing low-carbon heat and digital tech centres.**

Notes: [1] The are also a number of academics conducting research across the country but without a direct link to a research institute.

# The growth of digital technologies will need more digital, installation, and sector-specific skills to advance the sector

## Digital skills

Although the top leading sector in 2021 in generating inward investments into Scotland was digital technology (33 projects), an understanding of digital technologies seems to be missing across all low-carbon heat technologies and elements of the supply chain.

According to the Scottish Employer Skills Survey 2020, **over a third (35%) of skill-shortage vacancies** were due at least in part to a **lack of digital skills** (advanced or basic).

The interviewed industry representatives expressed concern regarding the missing skillset, especially in the realm of **software engineering, coding, AI, ML, IoT, computational tools, and digital twins.**

The **UK Government responded to the crisis with policies** and goals to increase the number of people successfully completing high-quality skills training in every region of the UK.

**Takeaway:** UK and Scottish governments must address the digital skills gap to provide enough specialists for the development of digital technologies.

## Installation skills

Looking at the uptake of digital technologies for low-carbon heating, a barrier is **the lack of installation workforce for low-carbon heating systems.** It has been articulated by various companies developing the technology that the number of installers is concerning, especially in rural areas.

The **scarcity of installation workforce keeps the installation of low-carbon heating solutions costly** independently of possible efficiency gains and thus cost reductions of the operation of low-carbon heat technologies through digital technologies.

The demand for heat pumps and heat network installers will **significantly exceed the current supply**. It is estimated up to 17,000 heat and network installers will be needed by 2030, where there are approximately 3000 skilled workers at present[1]. SG addressed the issue with a programme funding the certification for installers[2].

**Takeaway:** There are not enough installers to meet Scottish policy goals which will slow the infrastructure development.

## Sector-specific skills

To improve the energy efficiency of the building stock, it needs **new skill combinations**. Named were specifically the following connecting skills: **physics-based modelling, building design, building service engineering, and building physics.**

It has been established through the data collection that there is not enough human capital that has the right **skillset assembly to contribute with the expertise of developing digital technologies.** There is a need for engineers who know how to code and have experience, as well as software engineers with vast experience in the digital, where they possess a good outlook on heating systems.

Nevertheless, through initiatives of **Skill Development Scotland**, **Energy Skills Partnership**, and university partnerships, some of the gaps related to sector-specific knowledge start to be tackled.

**Takeaway:** Individual skill sets are not missing, but it's the combination that is needed. The skillset building required industry collaboration.

Notes: Takeaways based on desk research and interviews with the relevant industry actors; [1] Based on Clean Heat and Energy Efficiency Workforce Assessment conducted by ClimateXChange; [2] MCS Certification Fund provides heating engineers with a grant to become MCS certified on heat pumps until March 2023

# Several funding schemes are available but could be further targeted towards the supply side

SUPPLY → DEMAND

| Value chain | Upskilling University funding | Company capabilities building and R&D | Initial installation investment | Usage |
|---|---|---|---|---|
| Programs | **Digital Growth Fund** to address the undersupply of digital skills in Scotland's SME base<br><br>**Heat in Buildings Supply Chains Delivery Plan** is setting out a broad system of skills support for businesses working in the energy efficiency and zero emissions heating retrofit sector<br><br>**Funding for Digital Learning in Colleges** in Colleges | **DigitalBoost program** helps businesses with building resiliency<br><br>**Tech Scaler** funding for start-ups established by the Scottish government<br><br>**The Green Heat Innovation Support** for companies covering industries from manufacturing to technology innovators and the heating supply chain<br><br>**Digital Development Loan** by Scottish government<br><br>**Innovate UK** supporting business-led innovation in all sectors, technologies and UK regions | **Home Energy Scotland Grant** and 0% Loan for energy efficiency (EE) improvements, and for renewable measures for homeowners or self-builders<br><br>**District Heating Loan Fund**, managed by the Energy Saving Trust used for renewable technologies to build out heat networks.<br><br>**Heat in Buildings Strategy: 2022 Update**<br><br>**SME Loan and Cashback** scheme for the installation of energy efficiency measures and renewable energy technologies.<br><br>Scotland's **Heat Network Fund** offers capital grant funding. Both public and private sector organisations can apply<br><br>**The Green Public Sector Estate Decarbonisation** Scheme has been set up to provide capital funding to the public sector to enable retrofitting of energy efficiency and heat decarbonisation to existing buildings<br><br>The first **CARES** community buildings funding to install renewable technologies in Scotland's community buildings | **Domestic RHI**[1] offered a financial incentive over seven years to the household or property owner where a renewable heating system is installed.<br><br>**Non-Domestic RHI**[2] is an equivalent system, where businesses were compensated over 20 years based on their heat output |
| Target | • Private companies<br>• Colleges<br>• Individuals | • Private companies | • Private households<br>• Private and public companies<br>• Communities | • Households<br>• Private companies |

**Key takeaways:**

- The analysis shows that financial support is focused on strengthening the demand by subsidising the installation as well as the use of low-carbon heat technologies
- For SMEs in the heat sector, it is difficult to invest in digital technologies because they do not have enough resources and the understanding to know where to focus their capabilities in the digitalisation process
- Multiple interviewed stakeholders agreed that it is not profitable for heat pump manufacturers to expand their digital product portfolio without established demand. The installation of digital tech is not supported through funding specifically.
- Anyhow, the financial support needs to start earlier in the value chain, building skills, and the supply side, which can help create the innovations needed for consumer uptake
- Scottish Enterprise with Green Heat Innovation Support and Digital Development Loan has positioned funding on the supply side, which is in line with the findings

Notes: [1] Closed to new applicants in 2022 and replaced by Clean Heat Grant; [2] Closed to new applicants in 2021 and replaced by Clean Heat Grant

# The general digital technology infrastructure in Scotland is good, but not fully utilised in the heating sector

**The LoRaWAN® standard**
LoRaWAN is the fastest- IoT protocol globally and can handle large amounts of IoT units. The network is open-source and therefore not restricted to certain suppliers, thereby allowing for a broad range of applications

**IoT Scotland**
IoT Scotland is a National IoT network launched as a public-private partnership between the Scottish Government, Scottish Enterprise, Highlands and Islands Enterprise, and North.

The network delivers IoT connectivity across Scotland through the application of the LoRaWAN technology. It provides companies with an easy way to tap into the use of smart sensor technologies.

The network is the most advanced across the UK. Currently, connectivity is available in most larger cities and is reaching over 35% of businesses in Scotland.

## Deployment and utilisation of technology infrastructure in Scotland

Internet is the backbone of digital and smart technologies. Examples of necessary infrastructure include digital communication networks, data centres, smart meat networks, and smart energy distribution networks (Smart grid).

There have been significant investments in digital technology infrastructure in Scotland, such as a nationwide open-source IoT network (IoT Scotland) and the rollout of high-speed broadband connections. Additionally, several government-driven strategies and programs focus on advancing Scotland's digital capabilities.

While most of the digital infrastructure was not developed for heat, it has laid the foundation for increased connectivity of devices which could also benefit the heat sector. Additionally, it has helped develop the organisational capacity to help coordinate the future rollout of digital technologies for heating purposes.

**However, despite the large investments, there are challenges to the full utilisation of the infrastructure:**

- For many years, the general interest in heating systems has been low. For this reason, **consumers and companies have made limited investments in digital heating technologies**. The current hike in energy prices has increased interest, but a general lack of knowledge and available solutions is slowing down the transition.
- **Separated networks and a lack of common standards and incentives** to collaborate across sectors, systems and organisations have caused limited development of new digital technologies for the heating sector

**The interviewed stakeholders expressed similar considerations:**

*"Generally, a stronger collaboration between the heat and digital sectors would help eliminate technological barriers"*

*"I think Scotland is an early leader in data gathering, due to big deployments. Local authorities have deployed quite a lot which is further ahead than elsewhere. In metering we are further behind than elsewhere in Europe, they use different standards"*

Source: Interviews, Realising Scotland's full potential in a digital world - a digital strategy for Scotland: progress report 2017 to 2021

# Current building regulations drive some data collection in buildings but has the potential to do even more

**Regulations are creating a push for collecting building performance data, but a revision of the format combined with strengthened requirements could significantly increase demand for digital heat technologies in Scotland.**

## CURRENT STATE

It has been widely recognised in industry, academia and in government that the existing building regulations framework which captures building data amongst the non-domestic and domestic building stock is not fit for purpose. Apart from non-domestic new builds, data on existing non-domestic buildings are incomplete and of poor quality. For example, current EPC ratings are based on estimated energy costs for space and water heating.

## POTENTIAL FUTURE STATE

The regulatory design outlined in the Heat in Buildings Strategy builds on a proposal, consulted on in 2020, that owner-occupied homes be required to reach EPC C when they are sold or undergo a major renovation. From 2033 it is proposed that all owner-occupied homes should be EPC C. Currently, 60% of owner-occupied homes are below EPC C.

Additionally, a large amount of research and analysis is currently focusing on ways of improving the current methodology of building regulations such as EPCs by adopting more advanced methods of data collection. The Scottish government is currently consulting on a new EPC rating system as part of the Heat in Buildings Strategy which proposes an energy cost rating, carbon emissions rating and energy use rating.

A combination of increased strategic targets and more ambitious building regulations requiring more advanced data could significantly increase demand for digital heat technologies

### Regulations driving data collection in buildings

Currently, the following regulations are driving data collection from buildings in Scotland:

All buildings

- **Energy Performance Certificate (EPC):** The EPC shows a calculated rating (asset rating) of the current and potential energy efficiency of the building on a scale from A (most efficient) to G (least efficient). The EPC also includes an Environmental Impact rating, showing the calculated current and potential CO2 emissions from the building.

Non-domestic buildings only

- **Energy Action Plan (EAP):** Sets out measures to improve the energy performance of a building, including heating controls. Is required for non-domestic buildings over 1,000 m2 that are being sold or subject to changes in the lease
- **Display Energy Certificate (DEC):** Building owners can choose to implement the identified measures of an EAP or defer them by reporting a DEC on an annual basis
- **Energy Audits (EA):** The UK government has created the Energy Saving Opportunity Scheme (ESOS) for large companies, requiring them to undertake an energy audit every four years and making recommendations for non-obligatory energy efficiency measures

# Digitalisation of energy systems requires solutions to data collection, cyber security and privacy concerns

## Data

Systematic collection and analysis of data from buildings can support, amongst others, energy and performance contracting, smart load balancing, model-predictive building systems control, and preventive building maintenance. However, there are currently many barriers to sharing data from both the data ownership, data governing, and data sharing sides:

- The current data landscape in the built environment does not consider data as a public asset and consumers/building operators are sometimes not aware of the value of their data
- While modern buildings in Scotland are producing relatively good data, there is still a need to be intelligent about what data is metered and how
- Data that is collected often doesn't meet stakeholder needs
- There is a lack of standards and incentives for 3rd party operators to share their data

**Data in energy systems**: As the grid moves towards whole system integration and integrates low carbon technologies (e.g. solar panels, wind turbines, etc.) digitalised exchanges of data will be necessary for accelerating, automating, planning, and anticipating changes in the energy system. Consumers move from passive to active participants in the energy system. Examples of needed data points are flow rates, temperature, consumption, costs, and generation on a continuous basis (quarter, half-hour, or hour).

**Data from smart controls:** involves data about consumer energy usage captured from smart devices. This data is more granular and its volume is increasing with the implementation of smart devices.

## Cyber Security & Privacy Concerns

Programs encouraging the uptake of digital technologies and tools need to address cybersecurity and privacy concerns in order to earn users' trust and confidence. Clear communication is needed about what data is collected, who has access to them, how they will be used, and how they will be stored and protected.

There are existing **technical solutions** for ensuring consumer protection:

- Smart meter data can be de-personalized (through data aggregation/anonymization)to help preserve customer privacy
- There are numerous consumer data initiatives underway to help capture the benefits of smart metering whilst protecting consumers including; Ofgem's market-wide half-hourly settlement, The Public Interest Advisory Group, The Smart Energy Research Lab, and The DNO.

Cybersecurity and privacy ultimately should be addressed by the Scottish **policymakers**, who need to balance consumers' privacy concerns, promote innovation in demand response markets, and the operational needs of utilities. For example, Electricity Consumption Data is to be collected by each DNO, which first has to prove to Ofgem they have the infrastructure to ensure the protection of consumers.

The key aspect of the regulation is either an opt-in (affirmative customer authorisation) or an opt-out (mass participation with the option to decline) approach to customer authorisation.

# Consumers will be an integral part of the grid and their engagement is necessary to further drive the demand

Digitalisation allows the system to function more flexibly, optimising assets across our networks so that they may be integrated at the lowest possible cost to customers. Demand, supply, markets, and networks all need to be digitalised to produce an efficient smart grid. At present private customers struggle to relate activities to the cost of heating, they do not actively monitor the usage daily. Thus, new technologies require not only tailored solutions that stand for cost reduction, but also education **enabling behavioural change.**

In Scotland, two **pilot projects** were launched that challenged the role of the demand in the energy market, where either consumers who monitored their use and were rewarded for adjusting to the limited supply (Greenwich), or the whole community was fully integrated into the Smart grid (SMILE).

**Examples of demand participation**

- Selling energy generated from their energy (e.g., from PV panels or wind turbines).
- Using smart controls to shift their demand to periods of the day when prices are lower or scheduling heating times.
- Real-time control over energy consumption using the price signals technology and limiting the consumption over periods with critical load supply.

**Required technology and infrastructure**

- System integration relies on the network operator **National Grid ESO,** which leads the path and planning to system digitalisation.
- NG launched **Virtual Energy System** an open framework, with agreed access, operations, and security protocols. Over time, it is planned to be populated with digital twins (replicas of physical components in the system) and complex real-time data.

**Examples of required technology:**

| *Foundational* | *Basic Integrating into the Grid* | *Advanced* |
|---|---|---|
| • AMI / Price Signals<br>• HAN / LAN<br>• Web platforms | • Smart appliances / Intelligent Buildings<br>• Home Energy / Charging EV<br>• Real-Time Management Apps | • IoT<br>• Big Data<br>• AI |

**Pilot project examples**

**Greenwich Energy Hero**

To encourage behavioural change, the United Kingdom developed Greenwich Energy Hero, a digital service that installs smart meters in residences to measure energy usage. The software alerted users when power output in their area is low and compensated them for limiting their use during these times. The project held a 12-month trial in 2019 engaging more than 100 households with planned emissions investigation afterwards.

**The Project SMILE**

The project will be implemented in three different regions, including Orkney Island. To answer the local issue of fuel poverty, a Demand System Management is developed. The project relied on intelligent control (IoT) and aggregation of electric heating systems in homes, businesses, and city halls, as well as EV charging stations and hydrogen electrolysers.

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# Demand is fundamentally influenced by the vision, policy, and taxation of the UK and Scottish Government

**Policy targets**

**Scotland has pledged to reach net-zero greenhouse gas emissions by 2045**

**2030**
75% reduction in emissions relative to 1990

**2032**
Industry and commercial emissions reduced by 30% and energy productivity improved by 30% relative to 2015

**2045**
All houses in Scotland net zero

**Supportive legislation**

**Legislation in the following areas has been implemented to support the targets**

**Funding**
Incentivising adoption and scalability of new technology

**Taxation**
Lowering electricity prices and less-incentivised gas

**Sustainability**
Establishing reporting standards with transparency on GHG emissions

**Building performance**
Introducing strict building performance standards

**Energy performance**
Obligatory EPC certification and improved methodology

# The Government incentivizes the uptake of digital technologies with various funding programs influencing the demand

**Key takeaways**

- Heat decarbonisation policies in the UK have mostly concentrated on the demand side, such as energy-efficient retrofitting of existing buildings and enhancing the efficiency of current technology, which is largely dependent on digital technology development and application.
- The Scottish Government has committed £1.8 billion to the decarbonisation of the building stock. Dedicated national funds combined with the UK-wide schemes, result in Scotland dedicating the most public funding in the UK to decarbonisation.
- Apart from the installation of renewable heating systems, funding largely incentivises energy efficiency measures, including digital tech.
- In the context of Scotland, public funding is important to consider when analysing the demand drivers as it is the underlying mechanism that tackles barriers to the uptake of digital technologies, such as investment cost, lack of collaboration and understanding, and scalability.

## Support for private consumers

**Loans and Cashback**
Up to 75% in cashback grant (capped at £7,500) towards the installation of renewable heating systems and 40% for loans for energy efficiency measures.

**Pilot Equity Loan Scheme**
Up to £40,000 for eligible works (energy efficiency measures, heat loss reduction measures, and repairs) and repay when the home is sold or ownership transferred.

**Private Rented Sector Loan**
Scheme dedicated to landlords. Up to £15,000 for energy efficiency improvements and up to two home renewable systems per property worth up to £17,500 in total.

## Social housing support

**Social Housing Net Zero Heat Fund**
Over the next five years, £200 million will be made available to assist social housing landlords in installing zero-emission heating systems and energy-efficiency measures throughout their current stock. Funding is capped at £30 million each year.

## Collective and community support

**The Community and Renewable Energy Scheme**
Encourages the local or community ownership of renewable energy. Since 2010, provided £54 million in funding and for over 600 projects. Up to £175,000 in grant funding available. Current scheme period until 2025 is focused on heat decarbonisation.

## Multi-sector decarbonisation support

**District Heating Loan Fund**
Fund accessible to local governments, social housing landlords, SMEs, and ESCOs with less than 250 workers. Low-interest loans of more than £1 million.

**Heat Network Fund**
£300 million to support the development and rollout of zero-emission heat networks to all public and private sector applicants. Up to 50% of the total eligible capital costs of a project.

## SME support

**Loans and Cashback**
Maximum of £20,000 in cashback grant funding. Up to 75% towards the installation of renewable heating systems and up to 30% for energy efficiency measures.

# Demand can be divided into three sectors, each driven by specific requirements and technology

## Key takeaways

- The demand for digital technologies can be divided into three levels based on the customer type: private, non-residential, and industrial.
- **Residential demand** is largely influenced by the need for energy savings. In fact, more than 35% of all households report owning an energy monitoring device and the number is increasing each year. The barrier to growth is the lack of commercial understanding of digital technologies.
- The cost reduction and retrofitting of building stock drive digitalisation in the **non-residential sector**, where new technologies can benefit corporate compliance and energy performance standards.
- The **industrial** and commercial sector, which accounts for around 40% of total final energy consumption in Scotland can benefit from state-of-the-art technologies that will optimise heat and cooling systems and allow complex data processing, ultimately leading to reduced $CO_2$ emissions.

| | Residential demand | Non-residential | Industrial demand |
|---|---|---|---|
| **Market size** | • > 1.5 million owner-occupied homes<br>• > 500,000 houses in the social housing stock<br>• > 1 million homes switching to zero emissions heating system | • > 50,000 non-domestic buildings switching to zero-emission heating | • > 150,000 companies in the construction, manufacturing, ICT, and retail sectors |
| **Key actors** | • Private homeowners<br>• Landlords<br>• Building associations | • Public institutions<br>• Companies | • Large corporations<br>• Industrial manufacturers<br>• Utility companies |
| **Building segments** | • Residential buildings | • Offices/Retail<br>• Building complexes<br>• Social housing | • Manufacturing sites<br>• Warehouses |
| **Drivers** | • Energy savings<br>• Cost reduction<br>• Sustainability<br>• Retrofitting | • Energy savings<br>• Cost reduction<br>• Compliance | • Energy savings<br>• Cost reduction<br>• Compliance<br>• Emission reduction |
| **Requirements** | • Low-cost<br>• Simplification | • Low-cost<br>• Adaptability<br>• Monitoring | • Adaptability<br>• Monitoring<br>• Data processing |

# Retrofitting and energy efficiency standards are the key demand driver for residential buildings

## Drivers

### Retrofitting

- In the context of buildings, retrofitting can be defined as adding **new components** (hardware and/or software) to a property to improve its performance, where one of the key technological development is focused on **energy consumption**. Whole-house retrofitting of existing homes can significantly improve their energy efficiency (i.e., by 50% or even 80%).
- It is estimated that **1 million homes** will need retrofitting to improve energy efficiency measures/decarbonise heat supply by 2050.
- From 2020, The Scottish Government has proposed a **£4.5 million** payback incentive to assist homeowners and a **£4 million** to help SMEs install renewable and energy-efficient measures in their homes since costs of retrofitting is one of the biggest adoption challenges aside from technical and supply-chain limitations.

### EPC and Energy Efficiency

- Residential dwellings' **energy efficiency is improving**. In 2019, 45% of homes were rated EPC C or above, with social housing being more energy efficient (56% EPC C or better) than private housing (41%).
- The majority of private consumers (57%) **monitor their energy performance** with 35% of households owning an energy monitoring device. Year-by-year more people turn to digital technologies to lower bills and increase control.
- The governmental focus on reducing carbon emissions from housing will further drive the demand for digital technologies, especially in relation to **social housing**, which is easier for the Scottish government to control. Moreover, it dedicated more than £200 million to support the decarbonisation of social housing over the course of the present parliamentary term.

## Role of digital tech.

- Digital inputs allow **the energy savings from retrofits to be quantified,** using actionable data and real-time performance monitoring, creating confidence and certainty around retrofit performance.
- Smart energy devices, temperature, humidity, and $CO_2$ sensors, and the application of standardised methodologies/protocols will help **scale up retrofitting** by providing the evidence for developing new business models and financial products.

- The focus on buildings' energy performance and energy efficiency requires digital technologies to measure and improve these aspects.
- Digital technologies ensure that buildings are not evaluated at the stage of construction using an ideal use scenario (EPC), but are evaluated **by their real operating performance** measured using digital technologies and shared on digital platforms.

## Regulatory basis

### Heat in Buildings Strategy

- Owner-occupied homes will be required to reach EPC C when they are sold or undergo a major renovation.
- Developing regulations from 2023-2025 onwards and that all owner-occupied homes should meet a standard equivalent to EPC C by 2033. Currently, around 60%, or just under one million owner-occupied homes, are below EPC C.

### Smart Meter Policy Framework

- UK Government wants energy companies to provide smart meters to every home in England, Wales, and Scotland by mid-2025.
- Need to provide the technologies to 26 million households, where 20 million meters are already installed.

### EESSH

- The Energy Efficiency Standard for Social Housing (EESSH) aims to improve the energy efficiency of social housing in Scotland.
- All social housing to meet EPC Band B by the end of December 2032 (EESSH 2).
- Cost and investment concerns are counteracted with various public funding opportunities.

# Compliance and cost reduction will drive demand for digital technologies in non-residential buildings

## Market Potential

- There are roughly **220,000 non-domestic buildings**, including approximately 23,000 in public ownership. They account for 12% of energy use and 7% of total greenhouse gas emissions in Scotland. **Energy Intensive Industries** such as cement and oil & gas refining are emitting approximately **15% of national GHG**.
- Over **50% of non-domestic structures** are heated using low or zero emissions sources, however, they vary substantially in floor area and energy usage, with some of the largest non-domestic buildings having gas heating systems.
- Recently, **increasing energy prices** also influenced the industry, with many companies willing to optimise their heating and make it more efficient. Both gas and electricity prices have been highly volatile, with gas for the first-time surpassing in terms of cost, making electrification more economically viable.

### Cost reduction

- This is one of the most important drivers for digital technologies that are not influenced by existing legislation or incentive schemes.
- Digital products will become increasingly important as heating systems are electrified since they will allow consumers to take part in demand-side flexibility from the national grid, where heating consumption and storage can be influenced by the supply and price of power and gas.
- Virtual audits, which became more commonplace due to the pandemic, are cheaper to perform than traditional in-person audits and can provide expertise in remote areas where skills are lacking. Remote audits use a range of digital tools: including the IoT, sensors to monitor and prevent maintenance, digital twins, and 3D modelling.

## Corporate Sustainability Reporting

### Streamlined Energy and Carbon Reporting (SECR)

- From 2019 on, companies are required to report their energy use and associated greenhouse gas emissions. This also enforces reporting any energy efficiency measures implemented and state emissions using an intensity meter.
- Applies to all publicly-traded companies, large limited liability partnerships and large UK incorporated unquoted companies.

### Energy Savings Opportunity Scheme (ESOS)

- Applies to large companies and requires major organisations to do energy efficiency audits every four years.
- The mandatory audits are intended to identify optional practical and cost-effective energy-saving opportunities.

### Compliance

- The regulation related to corporate reporting on environmental sustainability is emerging each year, with increasing expectations and reporting requirements from corporations, thus, making optimisation of heating one of the conditions of a better score.
- The consumers’ expectations are evolving, pushing businesses to include GHG reporting and emission reduction across the value chain.

# High-end products are a growing market, but their current use in the industrial and non-residential sectors is limited

## Current Situation

The uptake of advanced digital heating technologies in the non-domestic sector is low. Only 10% of commercial buildings have a BEMS and the majority of energy-related building management is still undertaken manually using excel. However, new building regulations, energy costs, and energy targets have driven demand in a sector that demands highly complex solutions.

### High-end digital technology products

- High-end, technologically advanced products such as Digital Twins and modern/advanced BMS systems have been developed in Scotland for large-scale commercial buildings
- These digital solutions bring together a range of dynamic data from building sensors/metering including; energy consumption, occupancy, temperature, etc. and perform analytics to optimise the building functions as a “complex system replication”
- Energy prices, ESG commitments, scope 3 emission reductions, and increasingly complex regulations are driving demand in this sector
- Developing these products takes a range of advanced software engineering capabilities (e.g. buildings physics modelling)

## Technological Barriers & Solutions

- **Data gathering:** Requires the installation/location of real-time building information through the use of capture devices such as sensors and submetering. Also, 3rd party data owners might charge for the use of their data
- **Interoperability:** Amalgamating different data sources is complex, although some 3rd party companies are developing tools to overcome this
- **Costs:** Upfront costs of digital twins/advanced BMS systems are high and can require a lengthy installation and setup period; requiring the installation of sensors and meters if this data is not available
- **Skills:** Producing advanced representations of building performance and systems requires engineers with software & skills, building physics and modelling capabilities, and MEP (mechanical, electrical, and public health) engineering. These skills are considered to be in short supply
- **Compliance:** Building compliance is considered the most important mechanism for driving demand in this sector. Non-mandatory regulations such as (NABERS) were favourably reviewed as good practices in the industry.
- **Scottish Regulations:** The HiBS confirmed the aim to develop and introduce strengthened regulations to ensure that non-domestic buildings install a zero-emissions heating supply and reduce heat demand where feasible.

## Interview quotes

Two companies involved in digital twinning and advanced digital solutions for non-domestic buildings have been interviewed.

*“The complexity of trying to represent interacting systems in a building means there’s no one size fits all digital tool”*

*“Tools and companies are targeting this heavily because this is one of our biggest opportunities”*

*Interviewed companies: Hysopt and IES*

# New business models to facilitate the uptake and enhance demand for digital technologies

| | One-stop-shops | Collective purchasing | Heat-as-a-service (HaaS) |
|---|---|---|---|
| **Barrier** | The renovation and retrofitting of buildings is a **complex** process for consumers, which requires contacting **various suppliers** who provide unfamiliar heating options and control systems | **High initial expenses**, as well as **lack of understanding and trust** in the technology. Another issue is the **price uncertainty** and **lack of transparency** within the product offering**.** | **Upfront investment costs** as well as the cost associated with the **maintenance** of technologies are barriers for users. Suppliers struggle with **scaling** technologies to the domestic market. |
| **Business Model Solution** | • This business offers a holistic understanding of building, heating and digital requirements to be able to implement digital solutions efficiently.<br>• Brings together various suppliers across the value chain (e.g. installers banks, utilities) and provides explanation and inspiration.<br>• The tool analyses the data and recommends an optimised strategy to the renovation project.<br>• The client has one contact point, a single payment stream as well as assistance with financing. | • Allowing private customers to engage with collective procurement.<br>• Customers can benefit from the effect of economies of scale such as discounts from bulk buying of e.g., heat pumps and tailored digital technologies.<br>• Bringing together similar building types has an impact on reducing price uncertainty and increasing transparency.<br>• Peer support with choice, advantages and coordination. | • Heat pumps, maintenance, and heat are offered on a long-term basis by specialised energy companies to housing organisation, household owners, or utilities.<br>• Packaged service paid through a single subscription payment with assured savings.<br>• Digital technologies allowing a variety of financing option - paying for the amount of heat delivered to the home; paying for the temperature the home is heated to; paying flat-rate tariffs for the home to be heated; or combinations of these. |
| **Scottish Case Examples** | **Home Energy Scotland** is the most efficient one-stop-shop in the UK. It offers specialised guidance and financial assistance such as: home energy efficiency and low-carbon living. The service is focused on energy efficiency and, in the future, can become a platform promoting heat digitalisation opportunities. | **Loco Home Retrofit CIC** and **Zero Carbon Daviot** are community-based organisation that use neighbourhood-specific approaches to introduce decarbonisation technology at private homes. They serve as examples of institutions that could facilitate collective purchasing and networking. | **Warmworks** is a start-up modifying existing storage heaters to make the "Heat with Rent" proposition more financially viable. HaaS offers are beginning to emerge, but the offering still needs development before scalability and commercialisation is possible. |

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# Denmark and Scotland have very different characteristics, but learnings from Denmark could guide the Scottish transition

| Criteria | Evaluation |
|---|---|
| Regulations, Policies Incentives | Both countries have set **ambitious targets for decarbonising heat**, which are expected to **drive demand** for digital heat technologies. However, actual **regulations** supporting this transition are **more established in Denmark**, although Scotland is progressing fast. |
| Industry Capabilities & Structure | The **public ownership** and control of critical infrastructure in Denmark have created a strong foundation for local **cross-sector collaboration and innovation**, which has helped create global leaders within heat technologies. Collective ownership and sharing of relevant energy data sets have created a strong foundation for innovation with local companies. |
| Demand for Technology | Demand for digital heat technologies in both countries is driven by strong **global factors**. However, the structure of the **Danish district heating system** with non-profit public organisations controlling and developing key infrastructure in collaboration with local authorities has created **strong incentives to optimise** system performance through the adoption of digital technologies. |
| Society & Infrastructure | There is a strong **engineering** base **in both countries**, but **Denmark** is benefitting from a **higher level of digital readiness**. In combination with an advanced district heating system demanding advanced controls and strong market-leading companies in the country, this has resulted in a **strong R&D and skill development** within digital heat technologies in Denmark. |

## Takeaways

- The heating system structures in the two countries are very different. Denmark has highly developed district heating networks, making it one of the most energy-efficient countries in the world. On the other hand, natural gas is the main heating source in Scotland and the country has the lowest rate of decarbonised heat in Europe.
- However, very ambitious targets for greenhouse gas reductions accompanied by large funding schemes are likely to drive a strong transition in the country over the next couple of years.
- While the tools and pathways towards an increased rate of decarbonised heat will not the be same as in Denmark, a comparison of conditions and development in the two countries could inspire the adoption of relevant initiatives to support the journey and implementation new of regulations

# The Danish heating model is founded on four market and legal conditions determined by collective interest

**1 Natural monopoly**

Due to the economies of scale effect on heat production and networks, there is often only one local supplier. DH is most prevalent in places with a high building density (i.e. in urban and suburban areas). It is also present in smaller towns and big villages of roughly 500 homes.

**2 Non-profit principle**

The non-profit principle ensures the consumers are protected against abuse of the natural monopoly. The public heating supply is subject to non-profit rules and regulations. Supply services must not result in indirect taxation or subsidisation of the consumers.

**3 Decentralised structure**

Municipalities[1] have a critical role in community heating provision. They are in charge of heating planning and ensuring that the extension of DH and alterations to the DH system are in accordance with the heating supply law.

**4 Integration to the power grid**

DH systems remain a key element of the energy system as they allow short-term heat storage. This means that CHP plants may optimise their cogeneration based on electricity demand without jeopardising the heating supply.

## Differences in industry and legal structures

It is vital to understand the different system structures in order to allow the comparison between the industries for digital technologies in low-carbon technology in both countries.

The Danish industry has been shaped over the past 40 years, with digital technology being developed to continuously allow a more optimised and cost-effective system.

The decentralised ownership and non-profit structure created a natural demand for digital technology, where grid expansion and heat efficiency resulted in lower costs for all. The lack of privately owned gas distributors allowed the state to with time increase electrification and minimise the dependence on oil and gas with the interest of the consumers in mind.

The high dependence on gas in Scotland as well as privatised industry structure are a fundamental barrier to the adoption of district heating and other low-carbon technologies, and ultimately the application of digital heat technologies. There is no bottom-up incentive to switch to electricity, where the state must incentivise all steps of the value chain of low-carbon heat adoption. This directly affected the digital technologies which have not been commercially demanded.

**The underlying legal and market structure as well as decades of developing Danish digital technology for DH cannot be replicated in Scotland at present. Nevertheless, the Danish case offers learning points that could guide the transition in Scotland.**

*Detailed information on heating systems in Denmark and Scotland is included in Appendix B

Notes: [1] A village, town or city led by an elected council acting as local government

# Denmark has been developing the heating network for the past 40 years and created a supportive legal structure

**Danish legal framework empowered the municipalities[1], and with the state's guidance, it was in the best interest of local representatives to expand and optimise heating. This also resulted in high local demand for adjacent digital technologies.**

Since the **Heat Supply Act of 1979**, clear district heating regulation has been a decisive element in the widespread usage of district heating and combined heat and electricity:

- Local governments are responsible for approving new heating supply projects.
- Local governments must ensure that the heating project with the greatest socioeconomic advantages is chosen.
- Heat must be produced as combined heat and power wherever possible.
- The collective heat supply price must provide consumer pricing based on "required costs," which means that the heating price cannot be more or less than the actual heat production costs.

**The legal framework created a decentralised management structure integrated together through centralised policy**

- The legal structure constituted that municipalities[1] are managing the local supply and through full or partial ownership of infrastructure like DH, CHP, and WtX they integrate the local demand and supply for power.
- Local decision-makers have complete power over local heating system designs, but they do so by depending on a centralised policy and a national technical framework.
- The Danish Energy Regulatory Authority and the Board of Appeal within the energy area oversee the DH sector and deals with complaints regarding prices and conditions.

**Take-aways for Scotland**

- **Due to decades of policy development, the Danish legal system for DH is much more founded but the Scottish government is progressing fast.**
- The British and Scottish legislation, also influenced by the Danish Government[2], is on a good path to creating a legal framework for digital heat tech through:
  - Improved building stock
  - Corporate compliance standards
  - Elimination of investment costs through funding
  - Local heat efficiency strategies (LHESS)
  - Sector digitalisation and development of integrated networks
- Moreover, financial state support incentivises the adoption of digital technologies and increases energy efficiency.

**Key learning point**

The legal structure should facilitate local management of heating supply using community-oriented approaches, which create a national demand for technologies for heat optimisation.

Notes: [1] A village, town or city led by an elected council acting as local government; [2] The Scottish and Danish Governments already have established a strong partnership. Danish advice and experience have had a major impact on new adopted Scottish Heat Networks Bill.

# The Danish R&D and skills development in DH and digital technologies are equivalent to the industry maturity

**Years of industry development influenced the academic focus on DH and technologies supporting low-carbon heating. Denmark is leading in the digital transition and is developing a skillset in advanced technologies, only lacking the installers in terms of workforce.**

- ✓ **Academia and R&D supporting infrastructure development**
  Through decades of R&D initiatives in DH systems, components, heating production, and system integration, Danish research institutes and universities have accumulated expertise matching the level of industrial development. There are multiple internationally recognised universities with a strong teaching and research base in engineering such as the Technical University of Denmark, Aalborg University, and Aarhus University.
- ✓ **Leading the digital transition**
  Denmark is second best in human capital, connectivity, public digital services, and integration of digital technology in the EU[1]. The state has the ambition to lead the way in digital innovation, with a focus on regulated data standards, solid cybersecurity, and digital enhancement for enterprises. It has been named the most digitally competitive economy in the world because of its exceptional readiness to take advantage of digital change in the future[2].
- ✓ **Building R&D and skills in advanced technologies**
  When it comes to "traditional" digital technology, Denmark is in the lead[2], but it trails behind when it comes to the adoption of more recent, cutting-edge digital technologies, such as AI, the usage of Big Data, IoT, and IT Security. The Danish government is aware of this industry gap and is bridging it via research facilities for AI and digital technology and the training of STEM specialists. Compared to other European nations, notably the United Kingdom, the overall spending on R&D in digital technology is significantly greater[2].
- ✗ **Human capital lacking in installers**
  Even though the industry has been developing for decades, Denmark is critically lacking a skilled workforce in heat network installation. The training is often internally led by the DH companies and no policy has been developed to address it.

## Take-aways for Scotland

- **Scottish and Danish potential in R&D is comparable**, where Danish universities have established a focus on energy-related planning and engineering.
- Denmark and Scotland face the same challenge of lacking installers, especially considering both countries need fast technological improvement in the energy sector to meet their emission targets.
- The United Kingdom lags behind Denmark and the rest of Europe in terms of digital education and skill development at public institutions and private entities.
- Scotland's digital strategy resulted in continuing to improve connectivity as well as skill in computing.

| | DK | UK |
|---|---|---|
| Digital Competitiveness Ranking[2] | 1 | 16 |

**Key learning point**

Danish success in digital transformation relies on preparedness and adaptation to tech development. The future-oriented policies allocate funding to missing skill gaps and facilitate multiple public-private R&D partnerships.

Notes: [1] Digital Economy and Society Index (2022) conducted for the EU Members; [2] Based on IMD World Digital Competitiveness Ranking (2022)

# The Danish DH and digital technology industry is developed, with wide networks enabling collaboration

**The Danish district heating industry as well as its associated digital technology is well organized, and sector organisations routinely support global outreach and collaboration.**

**Government plays a fundamental role in structuring the industry**

The district heating, electricity, and natural gas industries are under the supervision of a specially created organisation called the Danish Utility Regulator (DUR). The DUR's main goal is to protect consumers' interests. This entails encouraging sector transparency, policy stability, innovative freedom, benchmarking, and price regulation, as well as monitoring and developing pertinent legal frameworks in accordance with EU regulations.

**Danish companies have a strong global presence**

Danish businesses that specialize in district heating, related technology and know-how have competitive advantages in the world market, and the district heating industry plays a significant role in the Danish economy. Notable examples include:

- **Kamstrup** holds nearly half of the market for heat meters
- **LOGSTOR** being a market leader in prefabricated district heating pipes
- **Danfoss** and **Grundfos** specialise in prefabricated district heating substitutions

**Industry supporting digital innovation in integrated grid development**

Denmark is the European leader in the development of smart grids, as accounts for 22% of all demonstration and development projects relating to intelligent power grids in the EU[1]. This is constituted on the basis of strong industry collaboration and state funds.

An example of an interdisciplinary industry network is **Flexible Energy Denmark[2]** – a digitization initiative aimed to establish a flexible demand for power. There are multiple innovative start-ups, most of which are university spin-offs, developing software and state-of-the-art data related to flexible demand analysis software like **ENFOR**, **Neogrid Technologies**, and **FlexShape.**

**Take-aways for Scotland**

- Danish industry collaboration is highly incentivised and supported by state **funding and policies on both national and EU levels.**
- In comparison**, Scotland has developed a similar strong policy orientation, but the facilitation of industry collaboration is missing**, as the funding is mostly allocated to the demand instead of the supply side (as elaborated on earlier).
- The Danish interdisciplinary initiatives are encouraging innovation in the field of digital technologies and providing **necessary resources for SMEs**, which often are lacking funding or data access.
- Scotland could elevate its potential in R&D and industry development through innovation centers and university collaboration, but **does not have national companies that are leading in the technological sector** related to low-carbon heating.

**Key learning point**

Supportive funding and policies facilitate and structure industry development and give the necessary resources to innovation needed in the technological sector.

Notes: [1] EU JRC Report (2011); [2] A 4-year-long state-funded project (2019-2022) with 24 participants from universities, utility companies, businesses, and public organisations

# Danish infrastructure is supported by the data-gathering and sharing opportunities reinforced by public ownership

**Denmark has a well-developed digital infrastructure and its collective ownership of DH and energy companies supports data optimisation and system interoperability.**

### Focus on the energy efficiency of the building stock

Due to stringent building regulations, a system for labelling energy-efficient appliances, public awareness campaigns, a requirement that energy certificates be included with home sales, and other residential and commercial efficiency policies, the building stock itself is focused on energy efficiency. All EPCs are listed on a public website and registered in a single database controlled by the Danish Energy Agency (DEA).

### Available information from the residential sector

In Denmark, all homes have a smart meter, which measures energy online. The meter updates the power provider on the household's use on a five-minute frequency. The meters are primarily used to gather information to compute use for billing, but by using them in a novel way, they may be utilized to gather crucial information for grid monitoring.

### Existing physical infrastructure

The elimination of gas and oil as energy sources is possible by replacing thermal generation with large-capacity heat pumps. The existing district heating infrastructure is ready to be used to be adapted to new low-carbon heat technology and will require very little work to make it fit for heat pumps.

### Collective ownership allows data sharing

The non-profit principle and largely state or collective-owned power companies make it possible to create an open-source platform. The state-owned gas and electricity company, Energinet.dk, gathers information on energy use from every Danish home and business as well as information on energy output from every renewable energy source. Their platform provides access to data on $CO_2$ emissions, power market statistics, and data on energy production and consumption[2].

## Take-aways for Scotland

- In comparison to Denmark, **Scotland is lacking the necessary digital and physical infrastructure** to facilitate the further development of digital technologies for low-carbon heating.
- Even though Scottish and British policies and laws are addressing the lack of data, especially from the building stock, **data sharing among privately-owned companies imposes a challenge.**
- Due to the difference in public/private ownership of power and companies network companies, Scotland cannot replicate the Danish model but instead develop policies pushing the private players to cooperate and standardize the data sharing with the interest of the consumers in mind.
- The regulatory frame in Scotland should similarly to Denmark allow for complex data processing.

| | DK | UK[1] |
|---|---|---|
| Domestic smart meters installed (2022) | 100% | 47% |

**Key learning**

The digitalisation of domestic and non-domestic sectors in Denmark is a fundamental step toward the further use of digitalisation to establish a whole system integration.

Notes: [1] Smart Meter Statistics in Great Britain: Quarterly Report (24 November 2022); [2] https://en.energinet.dk/energy-data/datahub/

# The focus on developing the Smart grid in Denmark relies on digital technologies as key infrastructure asset

**Denmark is already reaching a supply of 70% of electricity from renewable energy and a further increase is forecasted. To respond to the fluctuation of renewable generation DH and connected to it digital technologies act as the core solution, allowing flexibility and heating storage.**

**Integration in the power market**
In the Nordic power market today, all central CHP facilities and the majority of decentralised CHP plants sell energy, thus they adjust their production to the spot market's electricity price. When energy prices are high, CHP plant operators strive to produce both heating and power through cogeneration. They also make an effort to reduce production when electricity prices are low. Active utilisation of the system's heat storage makes this style of functioning easier. Furthermore, the market price of electricity is increased for power and CHP plants that use renewable energy sources.

**Increased system adaptability**
Some technological adjustments can increase the DH/CHP system's adaptability and facilitate the integration of wind power, such as *heat reservoirs*, *electric heaters, and boilers*, or *bypass power plants*.

- When there is enough power in the system, DH plants may reduce their CHP production and still be able to offer heating from the thermal storage by using *heating storage*
- DH plants may directly utilize extra power for heating production by employing electric boilers and heat pumps.
- A CHP plant can avoid producing energy when there is an oversupply in the system using the bypass of power turbines and focus solely on producing heat

**Future challenges**
The Danish energy sector is undergoing challenges with intermittent renewable energy resources (mostly wind power), electrification, and sector coupling as key drivers. Accepting the continuous shift from combustion to non-combustion heat generating and from district heating to individual heat pumps in low-density areas will be the issue of the future.

**Take-aways for Scotland**

- **The technological and industry trends in both countries are the same and aim at the whole system integration.**
- Both Denmark and Scotland recognize that smart thermal grids will become fundamental to the energy sector, where Denmark is well prepared for the challenge where multiple national research projects have been implemented.
- As Scotland has not adapted to DH on a national level, the Smart grid development instead lies in the heat pump uptake[1].
- **Denmark is one step further in reaching an integrated system**, as it already has a well-developed data-gathering framework, which means the technological development now focuses on the control, standardization, and integration.

**Key learning point**

Preparedness for future power grid development requires an existing and country-wide data collection framework allowing interoperability and data sharing.

Notes: [1]Flexibility of decarbonised systems investigated through project Re-Heat started by Scottish DNOs in 2022

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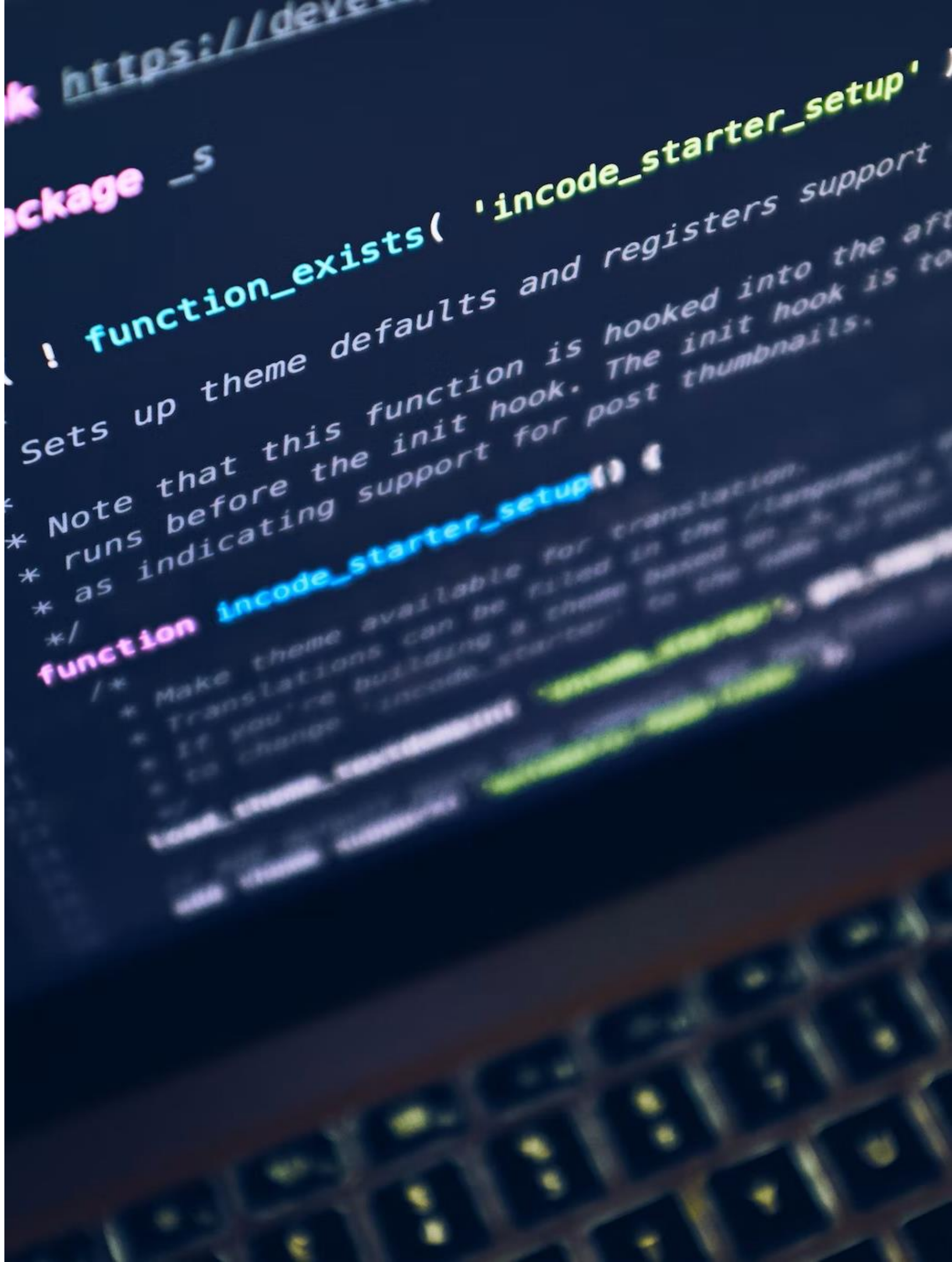


# Technology Identification (1/2): Input/Output technologies

*A total of 15 digital technologies were identified for the heating sector through our research and stakeholder engagements. Out of the 15 digital technologies, 8 have been categorized as "input/output" and 7 as "Process". Each is further detailed in this section.*

**Table 1: Technologies identified under 'Input/Output' category.**

| # | Technology Type | Technology Description |
|---|---|---|
| T1 | Sensors and transmitters | Provides accurate and real-time data monitoring for heating systems |
| T2 | Smart Metering System | Record and supply accurate and real-time data to control unit, user or utility provider |
| T3 | Smart Thermostat | Connect heating system to the internet, allowing access to user and control unit |
| T4 | Customer interface, software and apps | GUI enabling customers to feed and record information. Programs and apps for remote monitoring and control of the heating system. |
| T5 | Wireless/online data analysis | Enables data to be remotely collected by external bodies for billing or high level analysis of building stock |
| T6 | Smart Radiator Valves and Control | Regulate flow of material and heat distribution using inputs from user or central control system |
| T7 | Smart Heaters, Boilers, HP and thermal Storage | Regulate heat generation and storage using inputs from user or central control system |
| T8 | Digital Actuators | Regulate flow, pressure, temperature using inputs from user or central control system |

# Technology Identification (2/2): Process technologies

*A total of 15 digital technologies were identified for the heating sector through our research and stakeholder engagements. Out of the 15 digital technologies, 8 have been categorized as "input/output" and 7 as "Process". Each is further detailed in this section.*

**Table 2: Technologies identified under 'Process' category.**

| # | Technology Type | Technology Description |
|---|---|---|
| T9 | Operation control & self monitoring | The brain, logic based monitoring that reviews system operation control. Self learning/AI, digital twinning |
| T10 | Remote monitoring and diagnostic | Ensure early diagnosis of system errors to minimise downtime, maximise equipment lifespan and optimise system productivity |
| T11 | Adaptive learning & predictive simulation | Enable the device/equipment to accurately estimate the variations in operations and adapt to the variations. |
| T12 | Building Energy Management System | Equipped with data analytics to manage heating and cooling to reduce energy during peak periods. Provides centralised control for intuitive energy management |
| T13 | Heat Network Management Software | Operates individual system elements to supply heating while maximising efficiency |
| T14 | IoT, Big data, AI, ML, Digital Twin | Remote data collection and analysis for control and optimisation of a heating system. Digital representation of a heating system or component for performance testing and optimisation |
| T15 | Smart HVAC for Buildings | System components in a building HVAC allowing remote performance monitoring and control |

# T1: Sensors, Transducers and Transmitters

A Smart Sensor Device consists of three elements:

- **Sensing Element:** Also called a sensor, which produces a measurable response to change in physical conditions.
- **Transduction element:** Transforms energy from one form to another. Like microphone converts sound waves that strike its diaphragm into electrical signal that can be transmitted over wires.
- **Transmitter:** A device that converts reading from the sensor/transducer into a signal and transmits it longer distances to a monitor or controller.

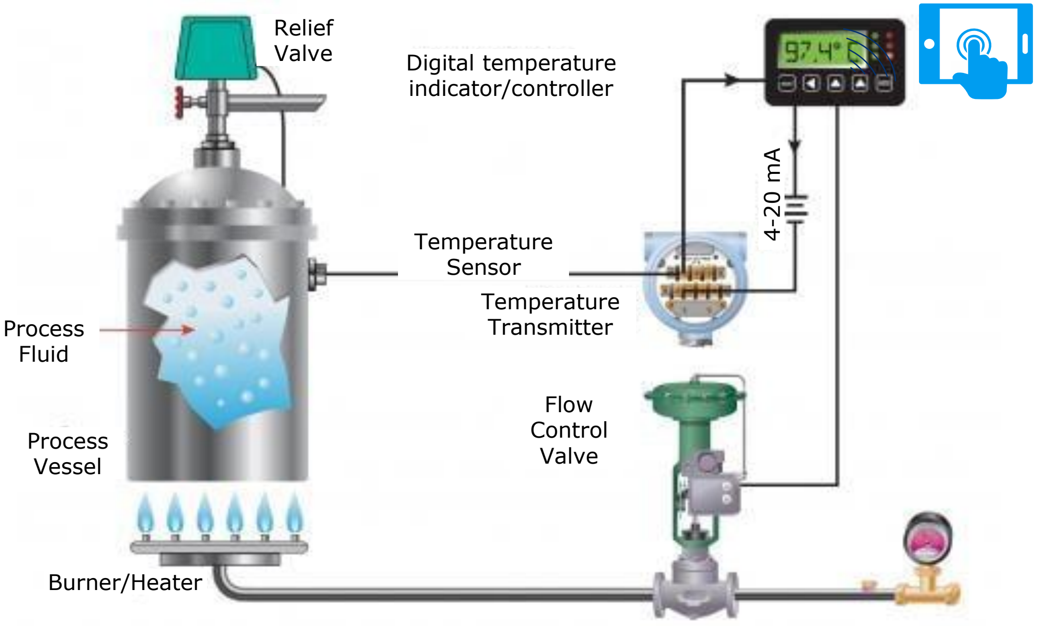



**Fig:** A smart temperature sensor arrangement for a heating process.

| | |
|---|---|
| **Quantity Being Measured** | Temperature |
| **Input Device (Sensor)** | Thermocouple<br>Thermistor<br>Thermostat<br>Resistive Temperature Detectors |
| **Output Device (Actuator)** | Heater (Flow Control Valve |

# T2: Smart Metering System

- A smart meter is an electronic device that records information such as energy consumption, temperature, flowrates etc and communicate the metered information with:
  - **Consumer** : For greater clarity of consumption behaviour.
  - **Supplier**: For consumption monitoring and customer billing. Eliminates manual monthly metering.
  - **Control Unit**: For system performance monitoring, control and optimisation.
- A smart meter allows bilateral communication between the utility centre and the customer.
- Depending on needs, smart meters can be designed to measure power (voltage, current, demand etc), water (flowrates), gas (energy, flow, demand), heating/cooling (flowrate, temperatures, demand).

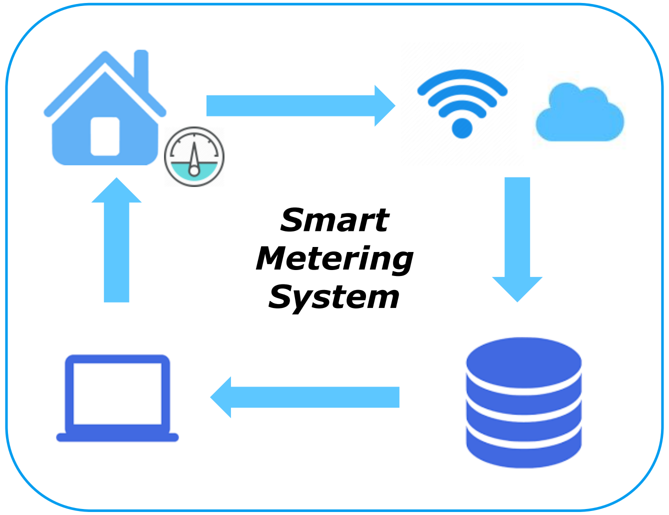
**Advantages**

- Allows data to be checked from anywhere through smart devices and enables real-time and accurate billings. They enable dynamic pricing.
- Allows significant energy savings.
- Smart meters can come with In-Home display units to monitor usage at anytime. Some smart meters can also inform the user on $CO_2$ emissions.
- The user can adjust habits to lower energy bills.

**Disadvantages**

Additional fee for installation.

- Privacy concerns for personal data collection.
- More responsibility on consumer for maintenance.
- Additional cost to train personal, develop equipment and implement new processes for data storage.



# T3: Smart Thermostat

- Same as the standard programmable thermostat, a **smart thermostat** controls heating and cooling systems to manage the temperature in a home. However, smart thermostats offer some advanced features over a standard one.
  - Sense occupancy and use energy only when required. Occupancy sensors are used to detect presence and Geo-fencing identifies occupants using location of their smart phones.
  - Monitor and control temperature remotely via smart phone or any device connected to internet or Bluetooth.
  - Automatically adjust temperature to meet preferences and activities.
  - Adapt schedule/settings based on behaviour (learning thermostat).
  - Allows "Smart Home" integration.

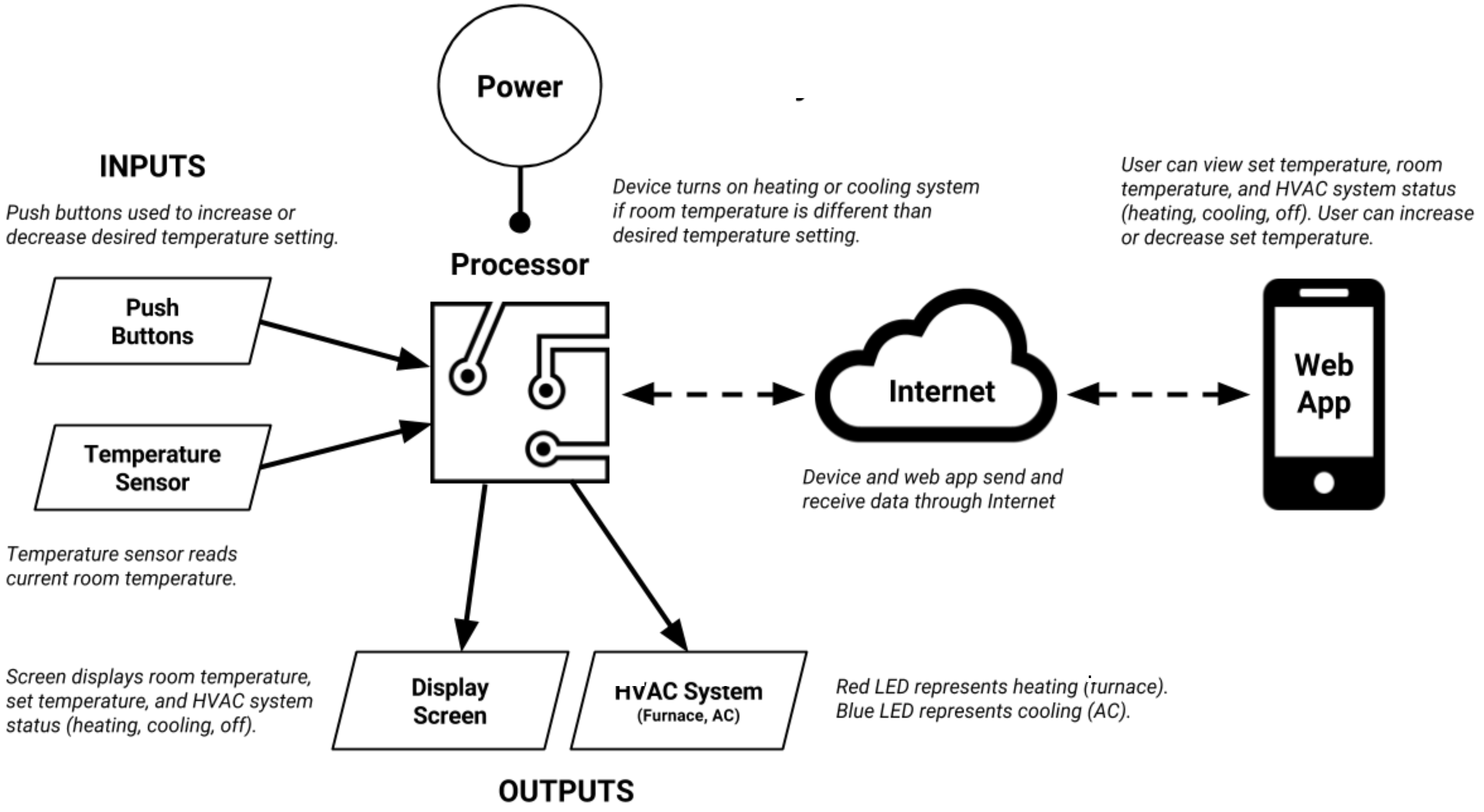


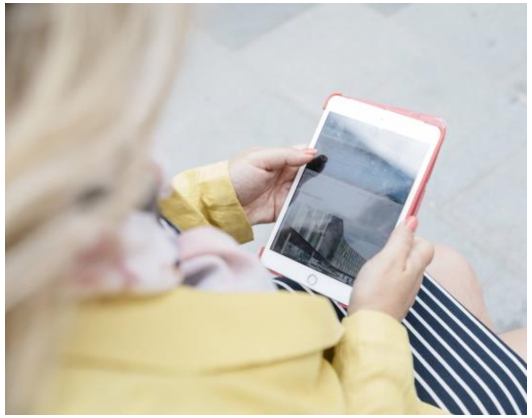

**Fig:** Smart Thermostat prototype system model

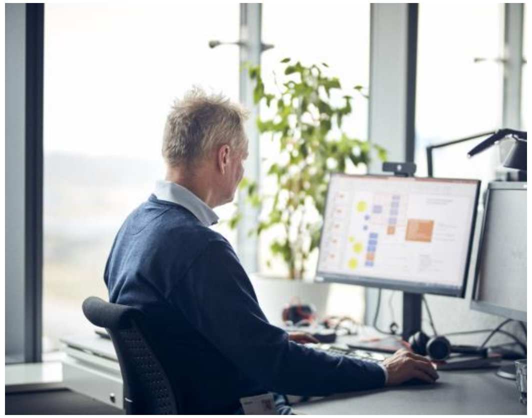


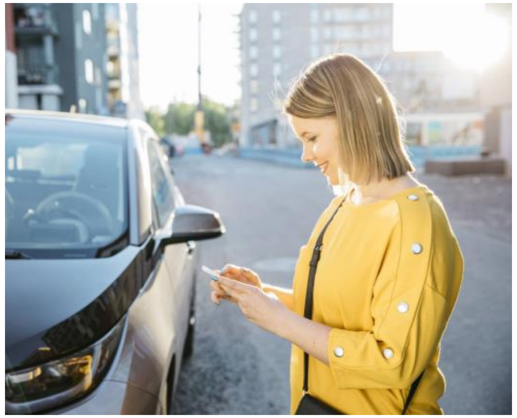
Source: https://docs.idew.org/internet-of-things-project/iot-project-outline/1-7-build-smart-thermostat)

# T4, 5: Customer Interface, Software and Apps; Wireless/online data analysis

- **Smart User Interfaces (SUI**) are human-machine interfaces, supported by software programs/apps, aim to improve the efficiency, effectiveness and naturalness of human-machine interaction.
- SUIs are physical remote controllers, tablets, wall-mounted control panels, smartphone apps that gives access to the smart heating devices and heating systems through wireless connections. The collected data is shared with a database where it is analysed and reported back to the user/controller of the heating system.



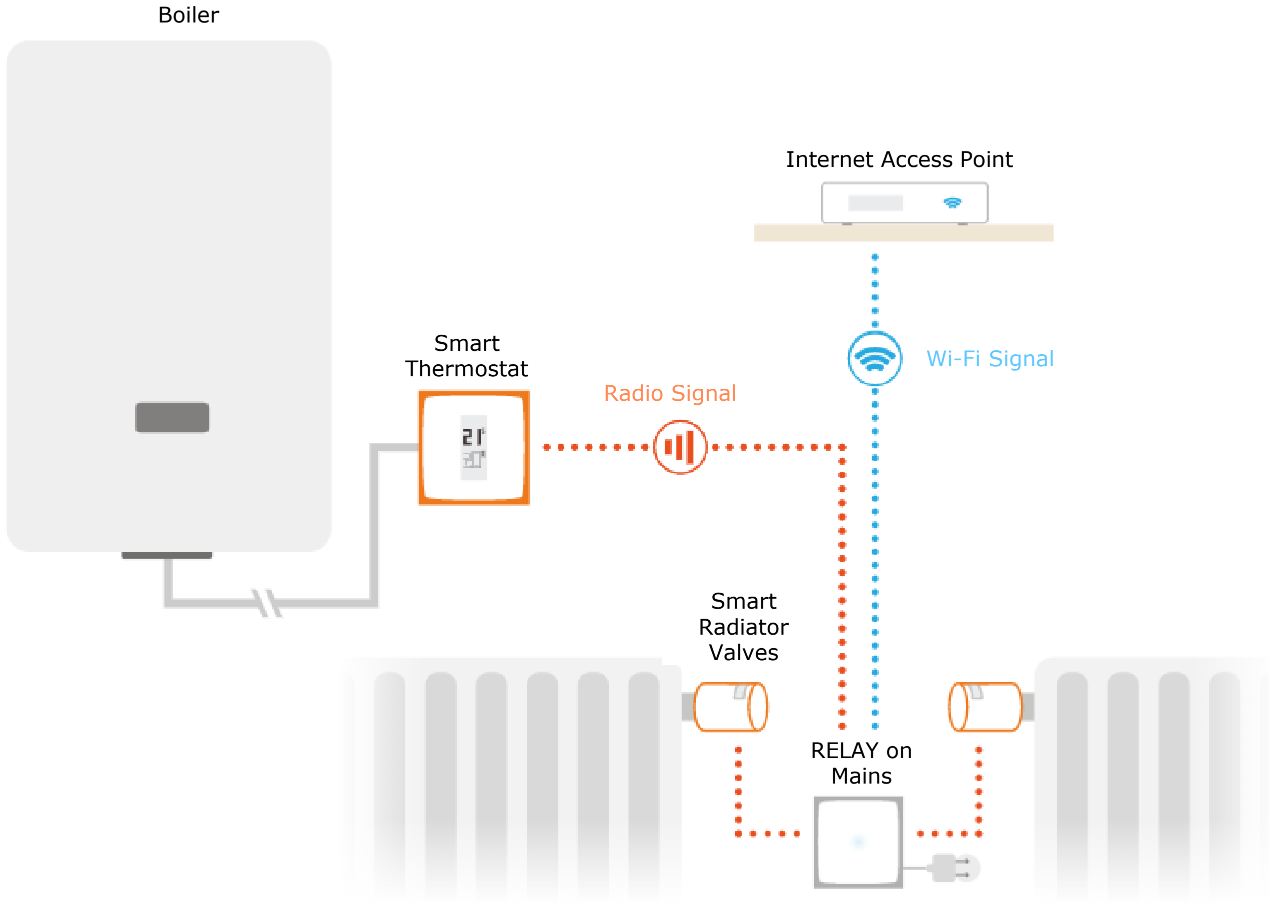




| Functionalities | Objective |
|---|---|
| High **update frequency** | Facilitate energy (heat) savings for customers |
| More **real-time metering** data | |
| Register **decentralised generation data** | Facilitate small-scale sustainable decentralised heat generation for customers |
| Provide **historical metering data** with date and time | Synchronise historical heating data with date and time between meters |
| Provide **heating costs** and related **$CO_2$ emission** data | Shows energy price information and savings resulted from habit changes |

# T6: Smart Thermostatic Valves and Control

- Smart radiator valves use the variation between the room temperature and set point temperature to regulate the hot water flow into the radiator in order to attain the desired room temperature.
- These **valves** can communicate with the smart devices and the central control unit through the internet to share the recorded and desired temperatures.
- The temperatures can be **controlled** through smart phones or manually, in absence of internet.
- This allows the user to save energy by heating only the occupied rooms while providing minimal heating to unused spaces.
- These valves can come with open window feature which detects sudden drop in temperature (typically by an open window) and temporarily turns down the heat.
- They can be set individually, according to the users schedule.






Source: : https://pro.netatmo.com/eu/additional-valve/installation

# T7: Smart Heaters, Boilers, HP and Storage

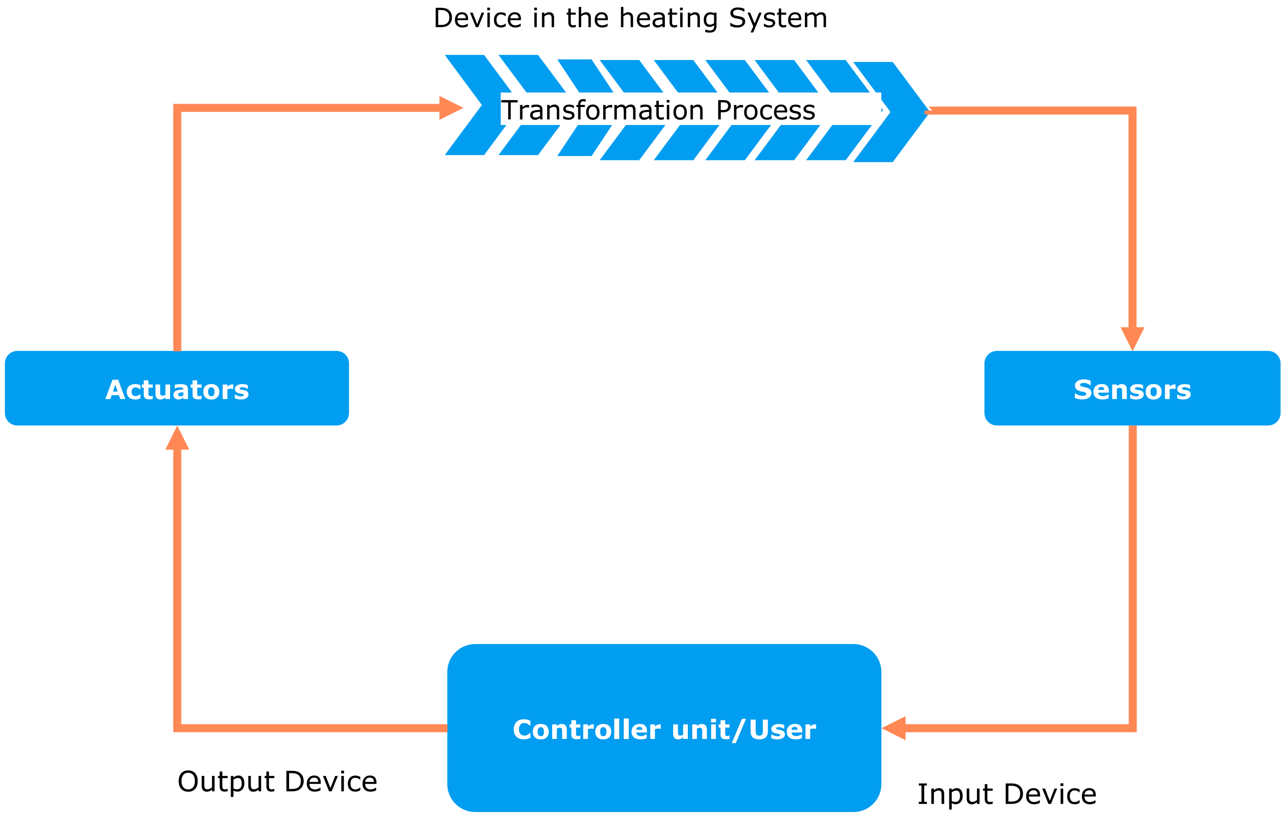
- A **smart heater, boiler, heat pumps and storage** allow control of the heating system remotely via phone, tablet or other devices connected to the internet.
- A smart heating system can be turned on/off from anywhere, as long as there is internet connectivity.
- It allows micro-managing of heating systems and saves energy consumption and emission. For e.g. set up on/off schedule remotely, and set different temperatures at different times.
- Smart heaters also come with Open Window detection features. This reduces the heating when an open window is detected and saves energy.
- The **Adaptive Start** feature allows learning the optimum heating time so that it can commence heating accordingly.
- Smart heater allows Zonal Control to use heating only where required.




Source: https://rointe.com/uk/wifi-controlled-electric-heating-systems)

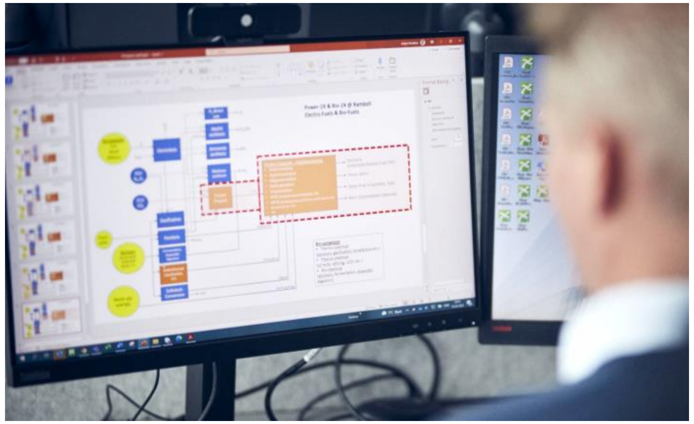
# T8: Digital Actuators

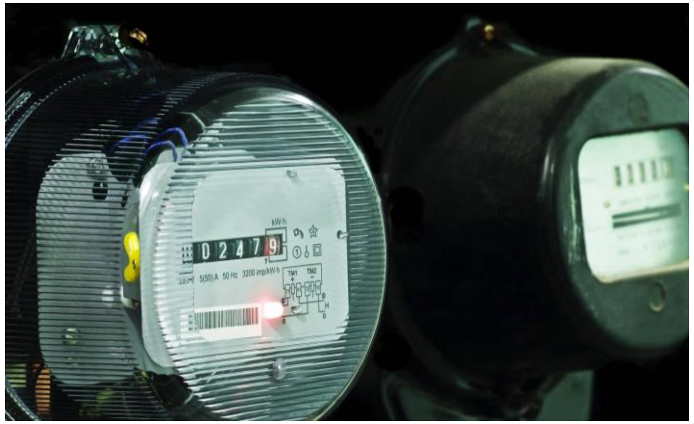
- A **digital actuator** can receive feedback or signals remotely from a computer program or mobile app and begins distinct motions depending on its purpose. These actuators can close or open a circuit, valve and devices in a heating system to obtain control and achieve desired output more efficiently, saving energy consumption for heating.
- Types of Actuators:
  - **Electrical Actuators**
    - Electric Motors : DC and AC Motors, Stepper motors
    - Solenoids
  - **Hydraulic Actuators**: Use hydraulic fluid to amplify the controller command signal
  - **Pneumatic Actuators**: Use compressed air as the driving force

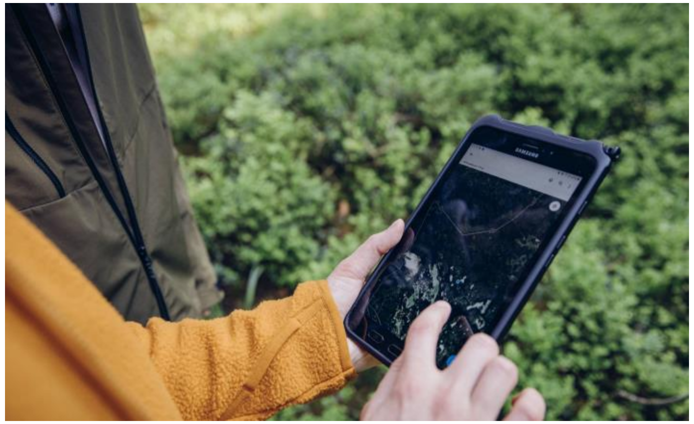


# T9: Operation Control and Self Monitoring

- **Accurate control** of the heating systems is vital to minimise energy consumption. To achieve this, manufacturers are adding advanced features into their equipment to allow real-time performance monitoring and control through programs accessible via smart devices or control units.
- For example, Mitsubishi Electric include MELCloud, a cloud-based solution, as standard for remote monitoring and control of their Ecodan heating systems.
- This enables either locally or remotely control and access
  - heating set point
  - system on-off
  - heating timers
  - live feed of local weather and outside temperature
  - hot water generation
  - energy usage, safety and error reports
  - holiday mode

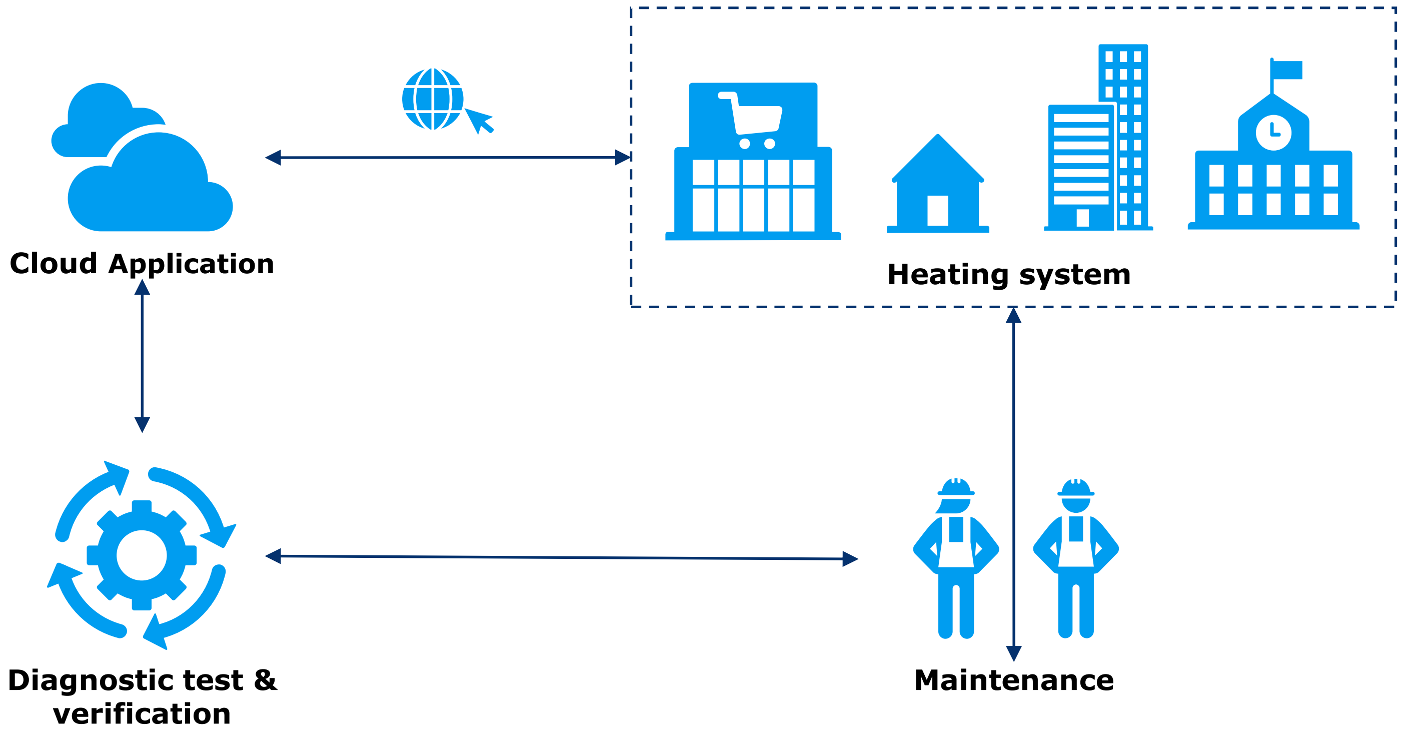






# T10: Remote Monitoring and Diagnostic

- The latest developments and innovations in monitoring and diagnostic techniques allows experts to remotely receive real time performance data of a heating system and identify possibilities of failures or causes of faults.
- This helps the maintenance team avoid failure by performing light maintenance in advance, decide whether they are needed on-site or find the right skilled person for maintenance. This maximises the productivity, maintenance period and operational life of the system.
- A **remote monitoring and diagnostic** solution consists of an intuitive cloud-based application and IoT enabling device, which detects the connected heating system and once connected, all brand specific parameters of the connected system will be immediately and continuously collected, analysed and presented in the application.
- A registered user or technician can have continuous access to the heating system and obtain real time alerts. All the service related parameters for the connected heating devices and system are collected for deep diagnostic where required.



# T11: Adaptive Learning and Predictive Simulation

- **Adaptive learning** and **predictive simulation** build on traditional machine learning techniques to create a more advanced solution to real-time environments with variable conditions. It helps the heating system adapt to the changes, making it more applicable to real-world situations. Instead of the on-off signal needed from the user in the classic on-demand-heating systems, the solution allows for higher predictability and efficiency.
- For example, hot water generation in residential buildings lies in the highly stochastic nature of domestic hot water demand. Learning hot water use behaviour enables water heating systems to continuously adapt to varying demand and reduce energy consumption.
- In predictive simulation techniques, data on demand, generation and temperature are continuously collected and analysed to create profiles for different days, months, time in a day and occupants – and predict the requirement in advance.

**Fig:** Smart water heating system

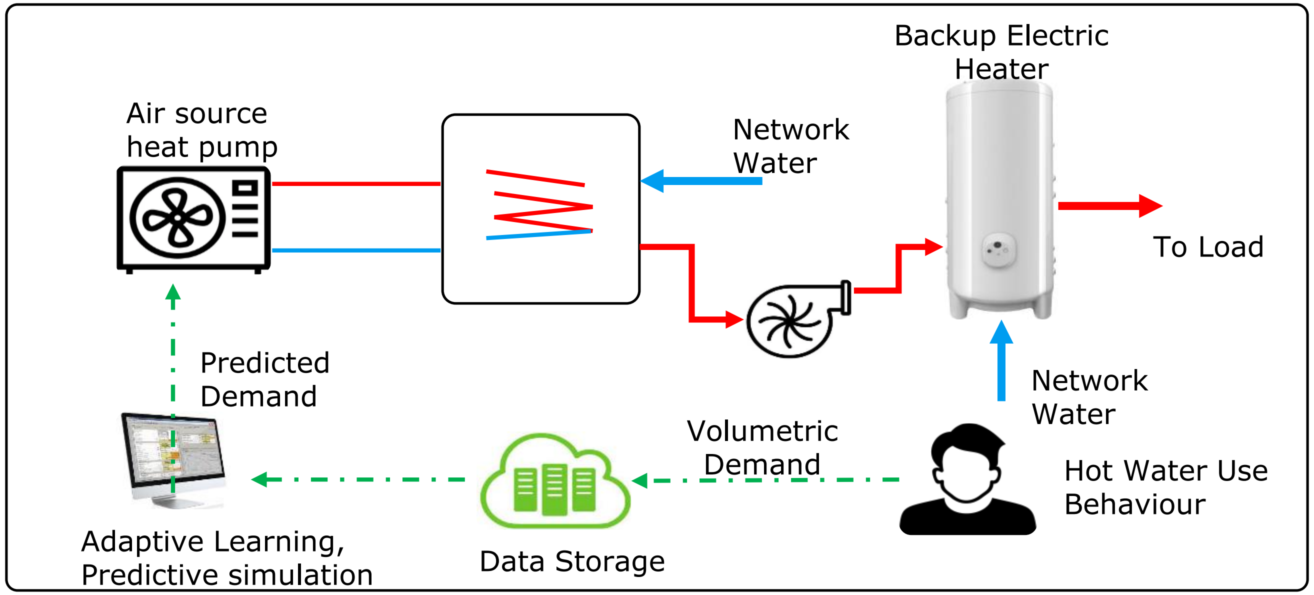
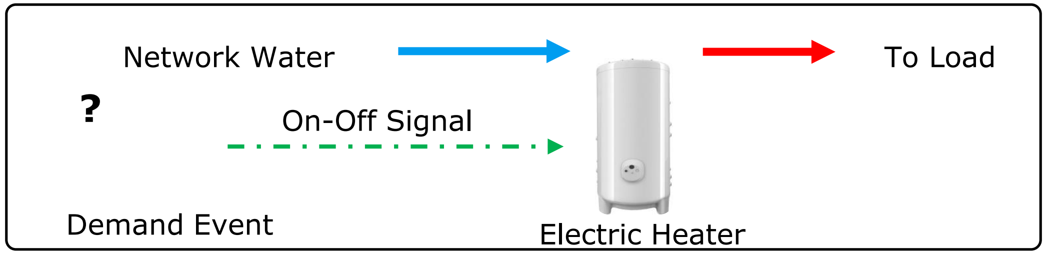


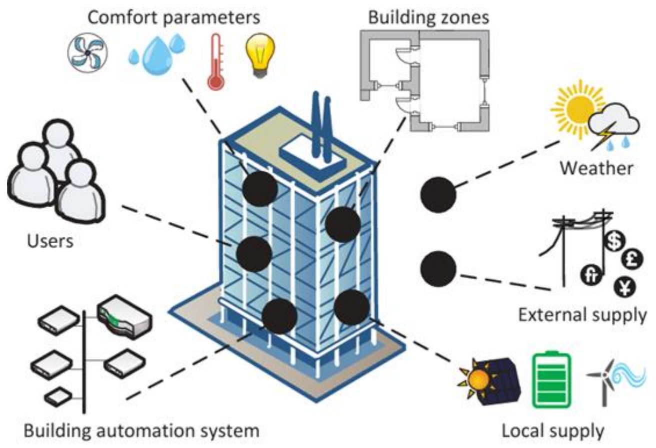

**Fig:** On demand system



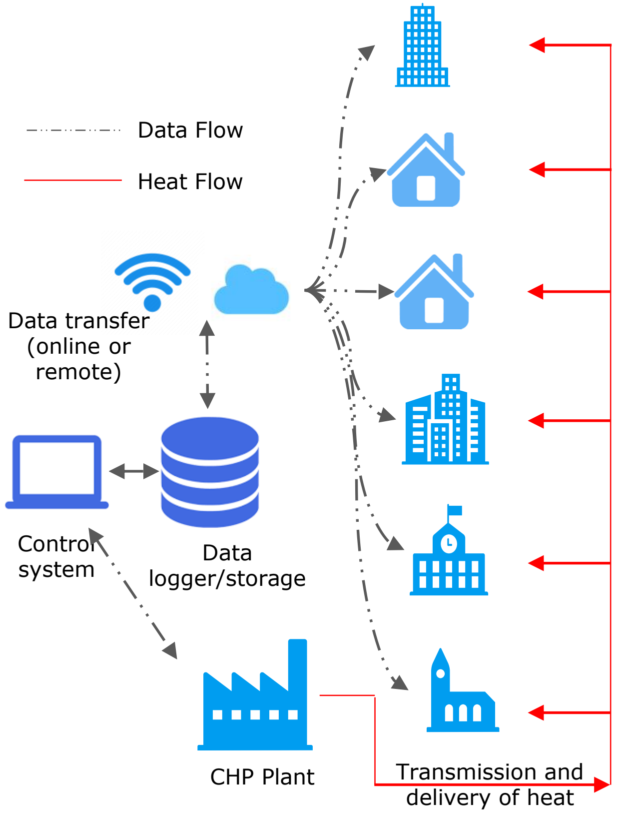
# T12: Building Energy Management System
# T13: Heat Network Management System

- Energy use in a building significantly varies on how the various energy-using devices are arranged as systems, rather than depending on the efficiencies of the individual devices.
- A **BEMS** monitors and controls all energy generating and consuming devices/appliances in a building to conserve energy.
- Components of BEMS for heating system may include:
  - Smart meter
  - Smart generation devices
  - Smart distribution devices
  - Demand response appliances
  - Energy storage
- Just like BEMS, a **HNMS** integrates different heat generation processes and heat demand sites in a heat network to monitor demand profiles and operate and control the generation system to precisely match the demand and minimise losses. It is a smart district heat network where demand and generation is matched through digital data transmission. This ensures that each element of the system is linked and can interact with others to maximise system efficiency.

**BEMS**




**HMNS**

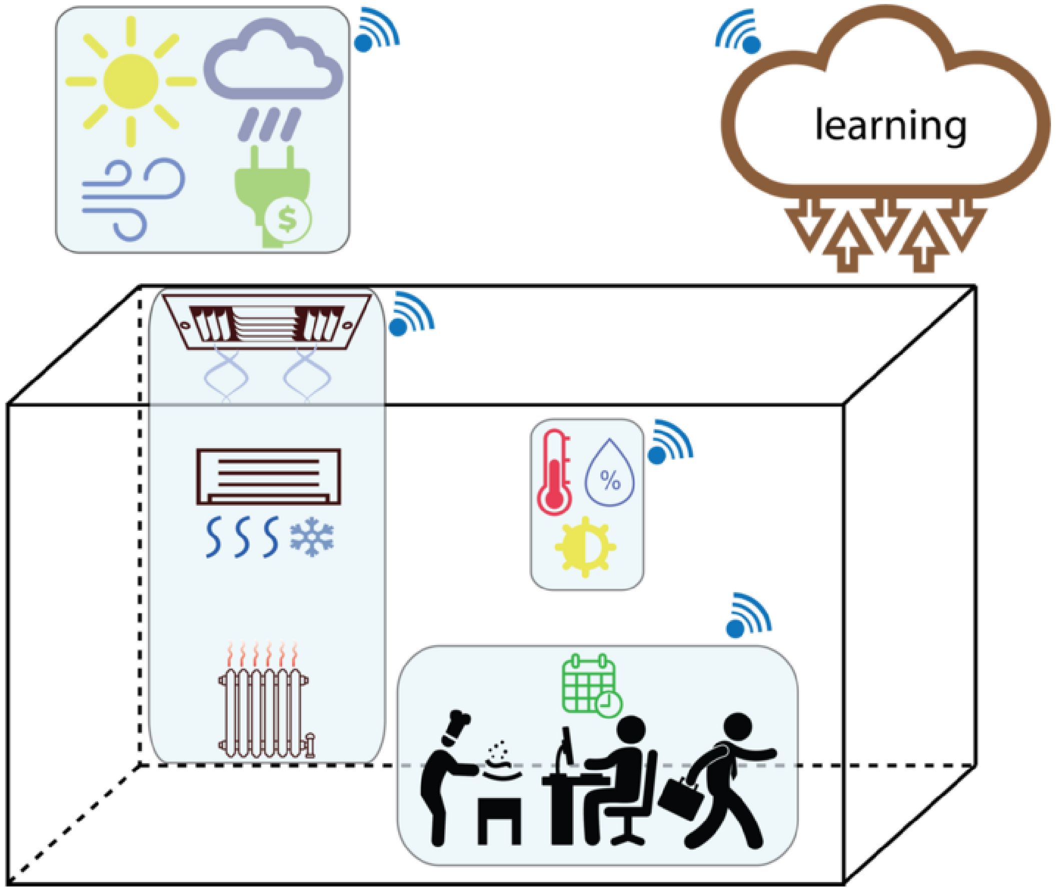





Source: https://www.semanticscholar.org/paper/Context-aware-optimisation-strategies-for-universal-Schachinger-Kastner/7a81be362eb8c3fdfa5ce19644d3ea00cbd0f4c0

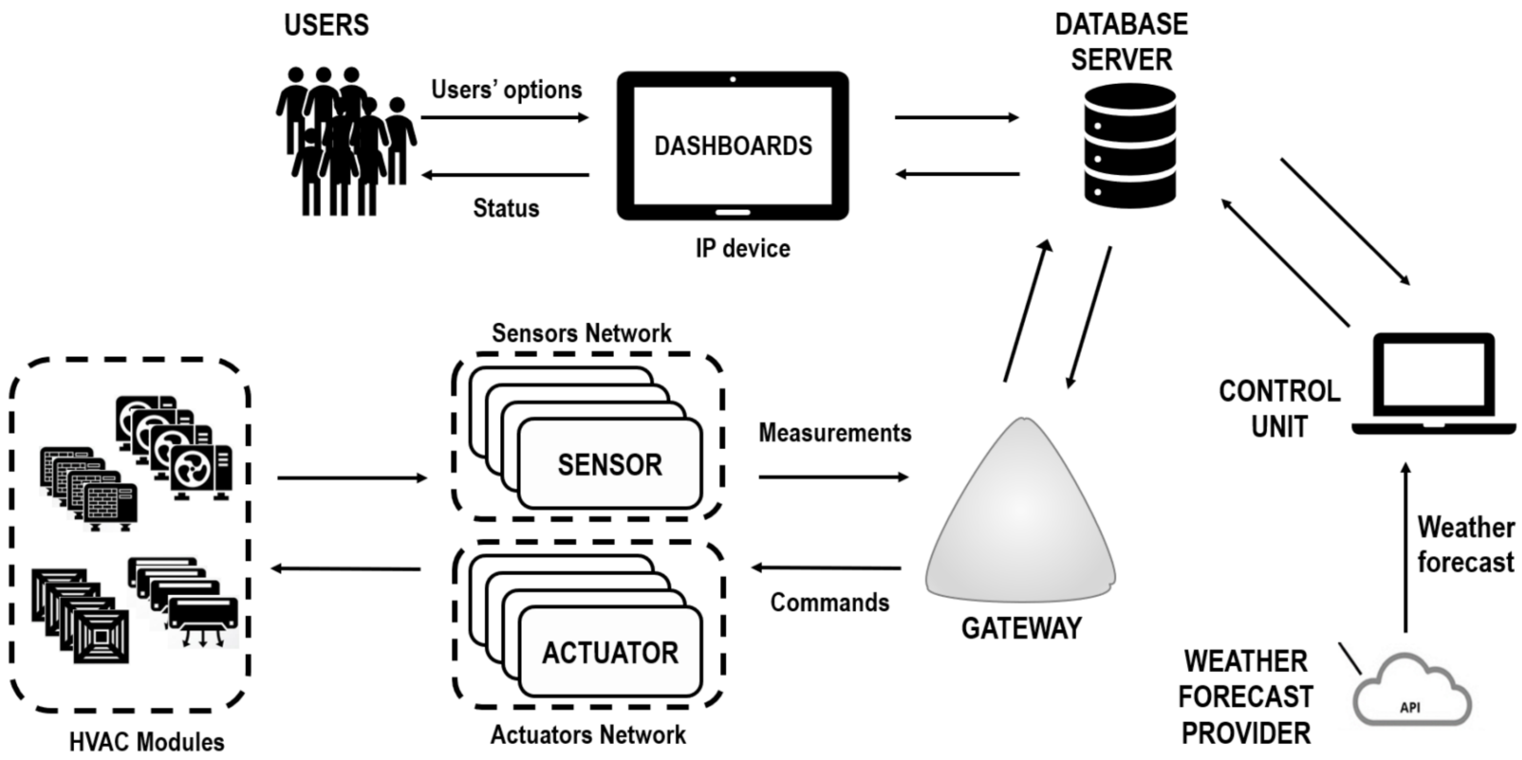
# T14: IoT, Big data, AI, ML, Digital Twin

- Adding smart features to heating products makes them efficient at individual level. To spread the benefit of Smart technologies across the whole heating systems, these smart heating products must be interconnected for greater & better monitoring, control & optimisation.
- **IoT, AI and ML** can deliver significant benefits to the building owners, district heating companies and residents. The IoT sensors continuously collects data such as building energy demand, ventilation and living patters of the inhabitants, weather conditions etc and sends it to the AI unit that processes the data. The ML software creates unique mathematical models for energy optimisation of the building. These models are then used to control the operations of the building's heating system.
- AI and ML automatically generates very precise and accurate mathematical thermodynamic models of the buildings it controls.
- **Digital Twins** are virtual representations of a physical system, like a heat pump or heat network, in the form of numerical models, which are constantly adapting to the current operating conditions in order to optimise operation.
- Digital Twins constitute the basis for a variety of services such as advanced systems monitoring, optimisation of system operation, and fault detection and diagnosis.



# T15: Smart HVAC for Buildings

- A **Smart HVAC** system connects individual components of the HVAC system with each other and a central control unit through internet or wi-fi connections. It uses sensors and actuators to monitor and control the overall HVAC system performance - to achieve desired comfort level in a space and minimise losses.





Source: https://www.mdpi.com/1424-8220/20/3/781

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# The heating system is key for emission reduction and energy efficiency in Denmark

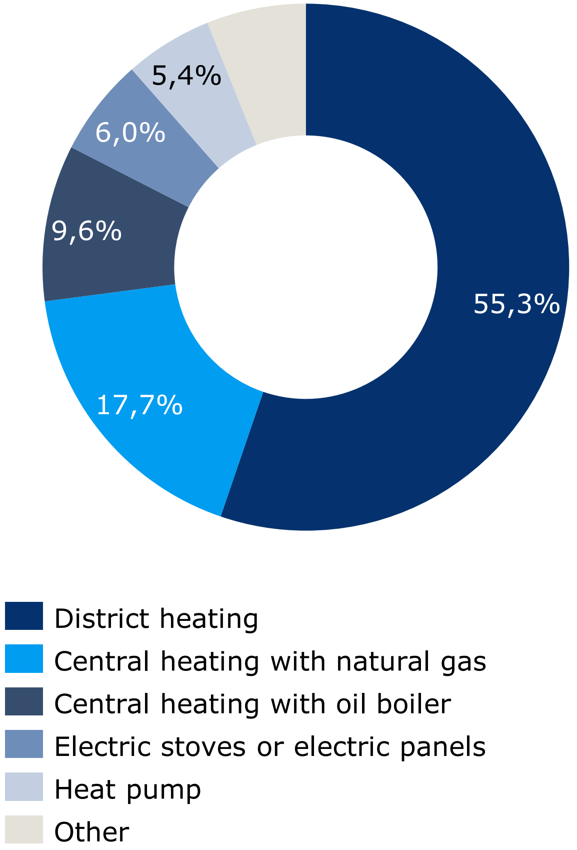
### Decarbonisation goals

- The Danish Government's objective for 2030 is to reduce greenhouse gases by 70%, relative to 1990 levels and the long-term target for Denmark is to obtain **net-zero emissions no later than 2050**.
- Denmark is one of the most energy-efficient countries in the world. One of the most fundamental reasons behind this level of energy efficiency and reduced carbon emissions is the widespread use of **district heating** and **combined heating and power** (CHP).
- Denmark also intends to further advance district heating and become **fossil free by 2050**. Currently, 40% of the energy mix used for district heating comes from non-renewable sources.
- Additionally, the state has ambition to have only **green gas by 2030**, and that no homes are heated with gas from 2035.

### Heating model

- The Danish district heating sector supplies 64% of all houses, making it **Europe's most developed district heating** supply networks.
- Denmark has six large central district-heating areas located around major cities and urban areas and smaller decentralised district-heating areas across the country.
- District heating production is **decentralised** since production is often dependent on proximity. The benefit of this scheme is that the more households are attached to the grid, the cheaper the heating costs will be.
- In addition to **municipally owned companies**, a considerable majority of Danish district heating businesses are run as **cooperatives**. This means that the cooperative is owned by its members and works to advance their mutual interests.

### Share of the heated area by heating type in 2021 (%)




**2050**
Net-zero emissions target

**~ 1.8 million**
Total number of households connected to district heating

**~ 64%**
Share of households connected to district heating

# Heat pumps will be strategically important to reach the net-zero target in Scotland by 2045

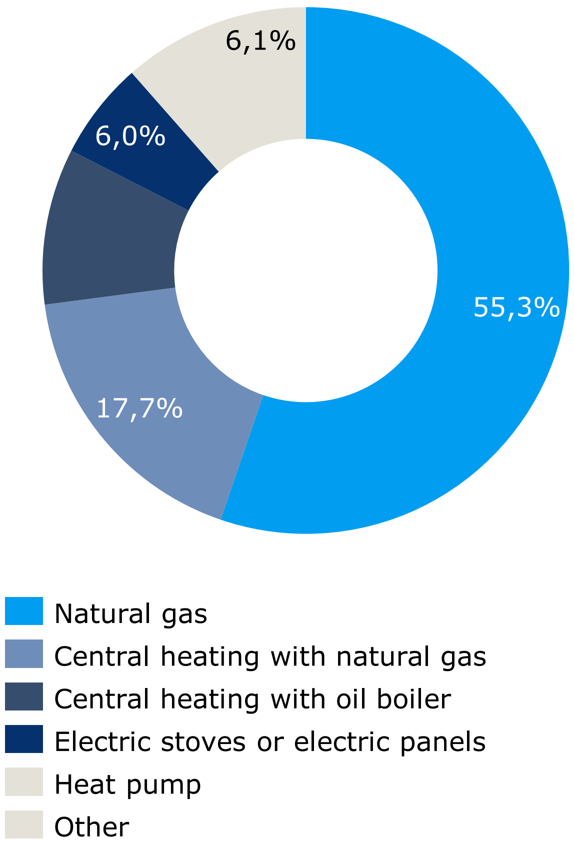
**Decarbonisation goals**

- Scotland's **net zero emissions target timeframe of 2045 is ahead of many other countries**, including the UK whose target is to reach net zero emissions by 2050. There is also an interim target of a 75% reduction in emissions by 2030, relative to 1990 levels.
- In Scotland, the energy consumed from heating contributes to **13% of overall $CO_2$ emissions** and makes up **30% of overall energy** consumption.
- Only about **11% of households** (about 278,000) have **renewable or low-emission heating technology**, such as a heat pump, biomass boiler, or electric storage heating. This excludes those already connected to a heat network, which is mostly powered by gas.
- **Heat pumps** will be a strategically important technology for delivering low-carbon heat in buildings as part of the goal of reaching net zero emissions by 2045.

**Heating model**

- The great majority of Scottish households rely on natural **gas as their primary heating source** (approx. 2 million).
- There are an approx. **1,080 heat networks** that deliver heat to **30,000 households** and 3,000 non-domestic properties.
- Scotland is regarded as a **forerunner in terms of UK-wide district heating legislation**, and Scottish regulation is expected to influence district heating development throughout the UK.
- The **Heat Networks Act (2021)** sets targets which are equivalent to an estimated 650,000 additional homes being connected to heat networks by 2030.
- The state incentivises the development of zero-emission heat networks through **funding** (e.g. Heat Network Fund) and **industry collaboration** initiatives like Expert Advisory Group (EAG).

**Primary heating fuel used in 2019 by type (%)[1]**




**2045**
Net-zero emissions target

**~ 30,000**
Total number of households connected to district heating

**~ 1%**
Share of households connected to district heating

Notes: [1] Latest available data from Scottish House Condition Survey 2019 (the survey has been suspended for 2020).

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