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Innovative technologies and tools to increase deployment of domestic heat pumps in the UK

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Abstract

The UK Government's Department for Energy Security & Net Zero has undertaken a 3-year innovation programme titled 'Heat Pump Ready' (HPR) as part of its £1bn Net Zero Innovation Portfolio. Heat Pump Ready is split into three complementary work streams. This paper focuses on stream 2 of the up to £60m programme which aims to support the development of innovative tools and technologies addressing barriers to domestic heat pump deployment across five thematic areas of: increasing the performance of domestic heat pumps whilst reducing their cost; minimising home disruption whilst providing high quality installations; providing financial solutions for heat pumps; improving the consumer journey through the transition to heat pumps; and creating a smart home energy system for heat pumps. This paper will provide an insight into the high-potential, innovative technologies and tools being developed under the programme across the thematic areas and their potential impact in supporting the deployment of heat pumps across the UK and in countries with similar climates and housing archetypes. [162 words]

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Keywords:heat pumps; innovation; supporting deployment;

1. Introduction & background

The heating of buildings is responsible for approximately 22% of the UK's carbon emissions [1]. Therefore, to meet the UK's legally binding net zero target, nearly all heat in buildings in the UK needs to be decarbonised. Without government investment in innovation and other measures to create an enabling environment for the large-scale adoption of heat pumps, gas boilers will remain the default for consumers heating their homes and there is a significant risk that net zero and interim emissions targets will not be met.

There are several potential solutions to meeting the challenge of decarbonising heat in homes and other buildings. The main potential decarbonisation pathways are: approaches involving electrification of heating, using heat pumps; those which rely on low-carbon gas, in the form of biogas or hydrogen; or a mixture of the two. In the short-term, electrification of heat is the only commercially available option for decarbonising heat. In order for the UK to meet its legally binding interim carbon budgets, it will need to rapidly scale-up deployment of heat pumps during the 2020s, both off and on the gas grid, from current levels, of about 55,000 in 2021 [2], up to the government's aim of 600,000 installs per year by 2028 [3].

Specifically, the HPR programme supports the ambition of 600,000 UK heat pump installs per year by 2028, which was set out in the Government's 2020 Ten Point Plan [3]. The barriers to overcome to enable a scale up of domestic heat pump deployment include: consumer acceptability, installer expertise and capacity, technology performance and cost, home suitability, electricity network suitability; installation quality and availability of financing options [4]. There are some solutions available to overcome these barriers, however, they are not at a commercial scale, or deployed most effectively, as part of a coordinated heat pump landscape. In responding to this challenge the UK Government's Heat Pump Ready (HPR) programme seeks to accelerate the development and deployment of innovative solutions in all these areas.

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The overarching objective of the HPR Programme (which is split into 3 complementary streams [5]) is to create an enabling environment for heat pump deployment at a significantly increased density and scale than current deployment levels. This enabling environment - to stimulate and support the high-density2 deployment of domestic heat pumps in the UK – is to be achieved under the HPR programme stream 2 – the focus of this paper - through the development and trial of innovative tools and technology and to address barriers faced across the landscape. The parallel stream 1 of HPR programme focuses on the development and trial of innovative methodologies and solutions for local coordination of high-density heat pump deployment, consumer engagement and network upgrades.

2. Heat pump ready programme development

2.1. Evidence review

During the process of designing the HPR programme, a Rapid Evidence Assessment (REA) [6] was undertaken on behalf of the department to review available evidence on heat pump innovation in the UK and internationally including identifying any gaps in research. The REA used four questions to help focus and guide the research:

1. Financial Innovations: What are the necessary financial innovations required to deliver a large-scale roll-out of heat pumps in the United Kingdom (UK)?
2. Low Voltage Grid Issues: What are the Low Voltage (LV) grid issues associated with a concentrated deployment of heat pumps and how can we mitigate these? What is the necessary size of a heat pump cluster to achieve appropriate grid impact learnings?
3. Roll-out Facilitation: What are the necessary innovations or learnings required to facilitate the large-scale roll-out of heat pumps? What tools or established processes of stakeholder coordination exist that could support the effective roll-out of heat pumps and are there examples of coordinated deployment?
4. Performance and Deployment: What are the technological improvements to the heat pump system and tools that could be developed to support any of the above aims - i.e. the large-scale deployment of heat pumps in the UK?

Analysis of existing literature focusing on these four questions included the following four findings:

1. Considerable research has been undertaken on the business models needed to stimulate the uptake of domestic heat pumps, particularly when coupled with other energy efficiency measures. However, while there is plenty of discussion of the different models few have been trialled in-situ and at scale. Further trials and development of heat as a service (HaaS) is required to increase consumer understanding, identify what motivates consumers, and address concerns around the disruption and long-term commitment element associated with HaaS.
2. The level of impact that the electrification of heat, through the use of heat pumps, will have on the LV network will depend on a number of factors that include rate of uptake and load profile. The body of evidence suggests that LV network issues (e.g. voltage problems or overloading) can be expected from a level of heat pump penetration on the LV network. The availability of field data is limited especially at a larger scale. In order for a deployment programme to achieve the appropriate grid impact learnings, the deployment size should target achieving heat pump penetration across at least 20% of dwellings on an individual LV network.
3. A clear theme running through the body of evidence, is the benefit of effective coordination between relevant stakeholder groups. A consumer-focused framework which considers area characteristics that define the stakeholder engagement strategy may lead to increased take-up. An increased understanding of how more effective and accurate modelling of local and household energy demand approaches can assist in both scheme design and management, and operational ease-of-use and performance. It is worth noting that the evidence base for question 3 suggests using the social aspects of this kind of rollout, e.g. consumer engagement and satisfaction as a metric to compare the effectiveness of various modelling scenarios.

[2] In the context of the Heat Pump Ready programme, high-density is defined as deployment of heat pumps to at least 25% of properties on a single low-voltage feeder, secondary substation or primary substation.

4. To bring the actual performance of heat pump systems closer to the projected performance, innovations which allow existing heat pump technology to perform in a more repeatable way could be of significant benefit. Several studies observed that there are installations where the performance gap is very small and there are installations where there is a significant gap. Potential areas where research and innovation are listed as being of significant benefit include design improvements, manufacturing, installation and monitoring, maintenance, and operation.

2.2. Heat Pump Ready Programme objectives

An assessment of the evidence as part of the rapid evidence assessment identified the following widespread key barriers to large-scale heat pump deployment:

- affordability: the high cost of heat pumps
- lack of availability: lack of a strong market presence
- lack of awareness: of systems and benefits by households and the industry
- acceptance: heat pumps are perceived to be harder to install and use than gas boilers
- consumer willingness: resistance against potential disruption during installations
- consumer behaviour: demanding and using heat as if it were being produced by a fossil fuel boiler
- long-term demand: lack of certainty required for investors and businesses

In responding to these identified barriers the key objectives of the £60 million HPR programme are:

- reduce the lifetime costs of domestic heat pumps (including capital equipment costs, installation costs and operating costs);
- improve the lifetime consumer experience of heat pumps (including the experiences of: learning about and choosing a heat pump and how to pay for it; having a heat pump installed in the home and living with a heat pump);
- stimulate innovative research and solutions to address the impact of domestic heat pumps on the electricity system;
- improve the interoperability of domestic heat pumps with other smart technology in the home;
- develop and strengthen partnerships between the many players involved in the domestic heat pump sector;
- develop effective approaches and products to engage stakeholders effectively on heat pump issues with homeowners and with the key players who can help to deliver high-density heat pump deployment across the UK;
- establish an evidence base to enable effective design and development of future heat pump policy and regulation

The HPR programme covers three streams. Stream 1 supports the design and trial of innovative, optimised solutions delivering a more cost-effective and higher-density domestic heat pump roll out. High-density deployment will be piloted in a number of areas across the UK. Stream 2 focuses on supporting the development of innovative tools and technologies addressing barriers to domestic heat pump deployment. Stream 3 is focused on capturing and sharing progress, evidence, knowledge, and lessons learned between all the different projects across the programme as well as developing tailored knowledge to disseminate amongst key stakeholders including industry.

2.3. Stream 2 objectives

Under stream 2 – which is the focus of this paper - the UK government has provided more than £15million in funding to support innovation to make heat pumps cheaper and easier to install, helping accelerate the UK's move away from fossil fuel heating [7]. The solutions supported are at Technology Readiness Levels (TRL) 5 to 7 at the start of the projects. A total of 24 projects [8] in England and Scotland were awarded funding under stream 2. Stream 2 objectives specifically relate to supporting the development of innovative tools and technologies addressing barriers to domestic heat pump deployment under five main category objectives:

- increasing the performance whilst reducing the cost of domestic heat pumps
- minimising home disruption whilst providing high quality installations
- providing financial solutions for heat pumps
- improving the consumer journey through the transition to heat pumps
- and creating a smart home energy system

2.4. Stream 2 tools & technology outputs

Each project runs for a period of either 18 or 30 months with the programme concluding by early 2025. The tools and technologies being developed can be categorised by the expected output in the following way:

- Apps being created, for example:
  - for installers to use to ensure correct heat pump install & commission
  - for surveyors to generate heat loss calculations, radiator sizing and heat pump sizing
  - for consumers/installers going through heat pump related decisions including selection and install process
- Control systems:
  - for utilising smart meter data to embed heat pumps in a Home Energy Management System to optimise behaviour of house/renewable technology
  - for remote adjustment of heat pumps
- Data utilization, for example:
  - smart meter data enabling thermal modeling of the home considering heat pump suitability and sizing
  - data-driven solutions for installer decision-making/upskilling. Data and learning from every installation undertaken captured in structured Case Studies (including post-installation assessment)
- Financial products:
  - low interest loan products for consumers spreading the cost over the life of a heat pump
- Heat pump design:
  - design solutions for non-traditional housing archetypes
  - remote survey tool for surveyors
- Manufacturing:
  - to include; redesign of heat pump assembly processes, reducing heat pump part-count, modular heat pump design
  - heat pump and energy storage system combining energy recovery from the wastewater streams leaving a house
- Software:
  - to predict & monitor fuel usage savings from heat pump & fabric savings
  - installer selection tool allowing consumers to request installation quotes from Microgeneration Certificate Scheme (MCS)[3] certified installers, filtering by name, type and location
  - to ensure improved assurance of heat pump design and installation to manage financial risk

This paper will explore these innovative outputs and their potential impact in more detail.

3. Overview of stream 2 projects by category objective

The stream 2 projects are categorized from an innovation activity perspective as either Industrial Research or Experimental Development.

Industrial Research can involve planned research or critical investigation aimed at the acquisition of new knowledge and skills for developing new products, processes or services or for bringing about a significant improvement in existing products, processes or services. It comprises the creation of components parts of complex systems and may include the construction of prototypes in a laboratory environment or in an environment with simulated interfaces to existing systems as well as of pilot lines, when necessary for the industrial research and notably for generic technology validation.

Experimental Development can involve acquiring, combining, shaping and using existing scientific, technological, business and other relevant knowledge and skills with the aim of developing new or improved products, processes or services. This may include, for example, activities aiming at the conceptual definition, planning and documentation of new products, processes or services. Experimental development may comprise prototyping, demonstrating, piloting, testing and validation of new or improved products, processes or services in environments representative of real-life operating conditions where the primary objective is to make further technical improvements on products, processes or services that are not substantially set. This may include the

[3] MCS works with industry to define, maintain and improve quality by certifying low-carbon energy technology contractors including heat pumps.

development of a commercially usable prototype or pilot which is necessarily the final commercial product, and which is too expensive to produce for it to be used only for demonstration and validation purposes.

3.1. Category objective 1: to increase the performance whilst reducing the cost of domestic heat pumps;

The five projects within this category objective are outlined below.

3.1.1.

In the UK, housing associations and local authorities often find themselves as large landlords managing sites of multiple homes. In working to understand the context of the existing heating system prior to the installation of a heat pump and through continuous monitoring and analysing of ongoing heat pump performance, this Guru Systems Ltd project's objective is to provide operators the ability to remotely adjust the heating system settings as required. The intended outcomes for this project are to enable reduced initial capital expenditure spend, improved heat pump performance in operation, resulting in fewer maintenance callouts, lower carbon emissions, and, more comfortable residents with reduced heating costs. Tools and monitoring equipment are being developed to allow landlords to actively manage their heating systems as part of the project.

3.1.2.

To improve heat pump manufacturing processes this ICAX Ltd project aims to tackle the cost barriers of heat pump deployment by designing and building a trial manufacturing assembly line for residential heat pumps, using analytical and physical tools. This is in order to offer a systemic approach to optimised manufacturing based on current intelligent manufacturing design and operation capabilities. By re-designing the heat pump assembly process, the objective is to reduce unit costs and increase product quality.

3.1.3.

By combining electrically-driven heat pumps with heat storing batteries the aim of this project is to shift heat production from times of peak electrical demand on the National Grid, enabling consumers to charge heating systems to store lower cost and lower carbon heat in anticipation of their peak heating demand. This Kensa Heat Pump Ltd project aims to achieve this by decoupling the times of heating demand in the property from the time of electrical heat production. By shifting energy demands, the project also aims to negate some of the challenges faced by the grid from electrifying and decarbonising heat.

3.1.4.

This Mixergy Ltd project aims to reduce the lifetime costs of domestic heat pump installation whilst delivering higher system efficiency throughout the year. In turn it is expected this will reduce capital and operational costs, ensuring a more seamless installation process and holistic approach to design. The project team are focusing on ground-breaking technologies which reduce installation complexity and elevate the seasonally adjusted Coefficient of Performance of real-world heat pump installations.

3.1.5.

Modular heat pump design may be able to provide significant cost and CO2 savings across the installation, operation and production phases. Ventive's heat pumps are demand responsive, fully integrated with indoor environment control systems providing integrated ventilation, heating, and hot water with free summer cooling. The Heat Pump will arrive pre-plumbed and pre-configured with monitoring and renewable energy storage to enable quick and simple installation. Since each home is different (size, heat loss, thermal mass, occupancy, user behaviour), the project will use an array of integrated sensors to assess the indoor environment and adapt the performance of each system, learning and optimising its operation to drive improvements in energy efficiency, energy storage and load shifting capacity.

3.2. Category objective 2: to minimise home disruption whilst providing high quality installations;

The six projects within this category objective are outlined below.

3.2.1.

This project aims to create a new method to optimise heat pump specification, design and management by using on-site measurement of building performance parameters as design inputs. Through using smart meters, low-cost sensors and newly established techniques to directly measure key performance parameters on a property basis, this Build Test Solution project aims to determine:

- how calculations and measurements can co-exist, the latter providing improved confidence as well as optimisation and calibration of heat pump system specification and design
- a publicly available protocol that defines the measurement options, the standards that must be followed, what the outputs must comprise and how these should be presented
- optimal delivery models with respect to the use of quick tests, low disruption short term monitoring and/ or use of existing smart infrastructure and Internet of Things (IoT) devices already installed.
- the role of ongoing measurement and condition monitoring services to validate system performance in-use

3.2.2.

This project focuses on creating a mobile app and web platform which supports the correct installation, commissioning and maintenance of heat pumps. The Guru Systems Ltd platform verifies outcomes and stores heat pump settings in order to benchmark for future maintenance and efficiency improvements, and acts as a training resource for new heat pump engineers. The modular nature of the product will allow for a dynamic service to provide apps and platforms for surveys, commissioning and subsequent maintenance which can be easily adjusted for different heat pumps and adapt to changing verification regimes depending on how the market evolves.

3.2.3.

Hoare Lea's 'Right Sizing Heat Pumps' project aims to reduce capital costs, operational costs, and grid infrastructure upgrade costs through developing a tool to properly size, efficiently monitor and optimise heat pump performance. This will be achieved by improving cost and viability through standardising the approach to sizing heat pumps.

3.2.4.

A free heat pump home survey and design tool to help consumers make informed decisions regarding heat pump installation providing a knowledge base to facilitate the national rollout of heat pumps. As there are different types of Heat Pumps available with vastly different applicability, thermal output, installation complexity and cost, Q-BOT Ltd's tool will help consumers confidently match the heat pump to the thermal demand of the house and other specific needs on a case-by-case basis.

3.2.5.

1 million non-traditional homes in the UK have poor energy performance, putting their occupiers at increased risk of fuel poverty, and presenting a key challenge to standardised energy efficiency measures that typically precede a heat pump installation. RJ Barwick's project will utilise the Energiesprong approach to develop optimum standardised whole house retrofit solutions for four of the most challenging and/or common non-traditional home archetypes. The housing stock of West Kent Housing Association & Gravesham Borough Council will be used for these pilots, with selected archetypes that have inherent design complexities, assisting the development of optimum solutions in the future. Each house has its own complexities and sharing of practical archetypal retrofit knowledge on 'hard to treat' non-traditional homes underpins this project.

3.2.6.

An all-encompassing integrated software package and app for installers to streamline the survey, installation and commissioning processes required when installing a heat pump. Thormer Solutions Ltd's project will provide a digital survey platform and a fully automated design facility. It aims to allows the system to be optimised from the beginning and uses augmented reality to provide the consumer with an upfront feel for how the system and components will look and sound when installed. The platform will also ensure that all documentation is stored and logged against the installation. There will be full traceability for consumers and installers to access in the future when it comes to heat pump maintenance and service. Overall the project will aim to streamline the installation process, significantly reducing the time and effort it takes to complete any installation.

3.3. Category objective 3: to provide financial solutions for heat pumps;

The four projects within this category objective are outlined below.

3.3.1.

This project aims to transform current understanding of heat in the domestic setting and provide a scalable approach to heat pump financing and deployment throughout the UK. This will be achieved via the prototyping, deployment, and testing of a Heat as a Service (HaaS) modeling solution, which will provide decarbonisation pathways and financing models. The City Science Corporation solution features a modular design, interacting to provide a full HaaS offering. Sub-sets of these modules will also provide highly valuable use-cases, for example by enabling key insights into which buildings heat pumps can provide a viable and attractive heating solution. Through the facilitation of a complete and accurate financing package, this project hopes to enable increased financing for combined heat pump and retrofit solutions, thus accelerating heat pump deployment at the lowest cost to the consumer.

3.3.2.

Heat pumps can deliver energy cost savings of over 50% when deployed as part of a high performance and high-quality retrofit. This creates an opportunity for a 'Comfort Plan' to be offered, which provides guaranteed heating outcomes for occupants in return for a fee (which is no more than the total savings). This could help to fund the heat pump retrofit enabling greater deployment and support access to heat pumps through reducing the requirement for upfront capital investment. This Energiesprong project will finalise the process and technology requirements to offer a seamless end to end Comfort Plan management service, and then develop and test the technical solutions required to enable delivery of this. Developments in this scheme will be shared in an initial contracted pipeline of 1,550 homes, aiming for solutions to be demonstrated within live projects.

3.3.3.

The aim of this Home Infrastructure Technology project is to develop a Green Homeowner Loan to pave the way for mass adoption of green home improvements, by developing a fintech platform specifically designed to fund heat pumps and other green measures. Aiming to be financially attainable, this has the aim to help gain consumer buy-in and increase the sale of heat pumps.

3.3.4.

This project from Parity Projects Ltd aims to directly address the cost and quality assurance barriers of decarbonising heat in homes, by creating a low-cost cost-effective options analysis and verification protocol to enable the offer of a financially insurable performance guarantee to homeowners and landlords. The project outcome will be software that integrates existing retrofit supply chain components to ensure improved assurance of design and installation of a suitable package of measures, with a particular focus on managing financial risk.

3.4. Category objective 4: to improve the consumer journey through the transition to heat pumps;

The six projects within this category objective are outlined below.

3.4.1.

The project aims to simplify and improve the efficiency of the heat pump installation process by creating a consumer-centric digital platform to support customers through the whole heat pump installation journey. This EDF digital solution aims to improve the customer journey by streamlining the required pre-installation steps into one remote survey, adopting a self-serve approach and reducing the amount of information required upfront. The outcome will be an end-to-end digital solution which will support customers in identifying innovative heat pump solutions, tailored to their profile. The solution will split into three main digital modules:

- pre-survey assessment using basic customer-provided data and housing stock data, determining heat pump eligibility or providing advice on other steps required (e.g. insulation) to become eligible
- remote survey and analysis, carrying out detailed design, quotation and installation plan
- post-installation monitoring and customer 'after care' package to build long term relationships with customers

3.4.2.

The project is proposing an artificial intelligence (AI) Smart Heat Pathway to enable rapid, high-quality and scalable heat pump deployment. This will be achieved through leveraging AI on Smart Meter and Smart Thermostat data to determine a personal net-zero pathway for each home, and size the subsequent appropriate heat pump, from actual measured data. Green Energy Option's project aims to help reduce the upfront costs of property survey and design and provide a viable customer success pathway towards net-zero heat for hard-to-treat homes. The project will be piloted across 150 homes, with the aim of scaling the AI Smart Heat Pathway nationwide subsequently.

3.4.3.

Hildebrand Technology Ltd's project is focused on improving the heat pump adoption customer journey, installer expertise, and outcomes by leveraging data from installations and enabling peer-to-peer learning and transparency. The project will provide a data-driven solution to reduce complexity and uncertainty for consumers and provide data, tools and resources for installer decision-making and upskilling. Data and learning from every installation will be captured in structured Case Studies (including post-installation assessment) to share insights in a structured, useful and engaging way. The goal is to create a feedback loop of peer-to-peer learning, among consumers and installers, that continuously improves advice and stakeholder confidence, based on practical real-world experience.

3.4.4.

This Switchee Ltd project aims to provide tools and research to overcome the current scaling barriers relating to heat pump acceptance, lack of awareness and consumer behaviour. The project is producing smart heat pump tools specifically aimed at improving the consumer journey for residents in Social Housing. This will be delivered by:

- allowing remote reading of error warning messages from the heat pump to alert the housing association
- using heat pump specific metrics including live and historic data. Heat pump specific algorithms will be developed to alert detected heat pump performance issues i.e. excessive energy consumption
- offering tailored heat pump advice focused on resident experience
- empowering the housing association to trigger when a new resident has moved into the property so that heat pump advice and educational material can be made available to them

3.4.5.

Developing a new consumer journey for heat pumps, guiding consumers from their first engagement through to receiving quotes for installation. The journey will build a technology selection tool based on the existing, tried and tested solution provided through Home Energy Scotland to assess a property's suitability for a heat pump. This will be linked to an enhanced version of the Microgeneration Certification Scheme's (MCS) 'find a contractor' tool to allow consumers to request installation quotes from installers. The project will seek an assessment partner, to increase the accuracy and dependability of the home information data. The intention being to provide multiple installers with sufficient information to quote to 90% accuracy, without the need for several pre-quote site surveys, whilst still complying with MCS standards.

3.4.6.

This is a software project aimed at improving the customer journey. Significant barriers need to be overcome at a household level to accelerate adoption of Heat Pumps technology and to meet the target of 600,000 system installations per year by 2028. These include costs, understanding of the technology, and appreciation of the long-term benefits (financial and environmental). VIA Analytics' project aims to help meet the 600,000 per year target by developing an online property level analytics platform enabling end to end management of the customer journey, particularly through:

- identification of suitable opportunities for domestic heat pump installations (and benefits) through digital customer engagement
- providing a platform that brings the customers and supply chain together in an efficient, optimised, digitally driven way

- developing a framework to provide accurate data management of engagement, installation, and post completion – with the objective of increasing investor confidence, to promote accelerated investment into heat pumps technology

3.5. Category objective 5: to create a smart home energy system.

The three projects within this category objective are outlined below.

3.5.1.

Creating a heat pump specialist Home Energy Management System (HEMS) supported by a full-package solution to help customers understand and maximise the benefits to their home. The Gen Game project aims to reduce costs and carbon by:

- using smart meter data to identify customers who would benefit from heat pumps and inform them of savings
- sizing heat pumps based on a variety of data sources
- optimising home energy management systems across heat pumps, PV, electric vehicle charging, battery storage and other energy assets to reduce costs and carbon
- providing access to flexibility markets to enhance the benefits and business case
- remaining energy supplier and product manufacturer agnostic, giving customers choice

3.5.2.

This Thermoelectric Conversion Systems Ltd project aims to overcome several major infrastructural challenges of heat pump adoption, by harnessing demand-side management to cope with peak loads and time-shifting energy use. By utilising otherwise wasted energy, this solution aims to give economic and reliable products for retrofit in existing homes and new-build properties to dramatically improve energy efficiency of buildings and cut running costs. The aim is to achieve this by:

- drawing energy from the household wastewater stream by re-using energy lost, e.g. from the shower or bath, by fitting the heat pump in the drainage system to recover energy stored in a hot water cylinder
- using a small air source heat pump to 'top up' the hot water tank temperature to provide the domestic hot water supply
- operating both heat pumps from a mains plug
- using a smart controller to manage both heat pumps and integrate with demand-side management systems to ensure sufficient hot water and heat are available

3.5.3.

The final project is working to overcome the key technical barriers to integration and energy performance optimisation, reducing running costs of heat pumps, and more broadly support improved end-user experiences and acceptance of these systems. The Wondrwall project aims to achieve this by optimising energy management to provide a platform that underpins advanced time-shifting strategies alongside proprietary artificial software intelligence software, using machine learning for dynamic predictive modelling of energy requirements based on their patented sensing technologies.

4. Potential impact of developing the innovative tools & technology

This next section of the paper considers what impact collectively the development of the tools and technologies under HPR Stream 2 may have on supporting meeting the category objectives listed in section 2.3 of the paper.

In order to increase the performance whilst reducing the cost of domestic heat pumps there is a real focus on the manufacturing of heat pumps and how innovation can positively impact current practices. This encompasses tackling the high number of parts utilized in heat pump manufacturing and reducing this where possible to bring about cost savings. In a similar vein modular heat pump manufacturing is being closely looked at as this may also have cost saving benefits. Taking a detailed look and reassessment of how heat pumps are assembled may also enable cost savings which could be passed on to consumers in time. Efforts focused on reducing installation complexity may also support the objective of reducing costs. Finally, it will be worthwhile to quantify potential cost savings that can be made in the remote controlling of a portfolio of operating heat

pumps through, for example, a housing association. Allowing heat pump operators to adjust settings based on continuous monitoring should allow identified savings to be realized across capital expenditure, lower maintenance costs and improved performance.

In minimising home disruption whilst ensuring high quality installations there is a real focus from the funded projects on producing mobile phone apps for a range of people involved in the process of getting a heat pump.

Taking the consumer (e.g. home owner), as an example, a whole range of information needs to be considered by them in order to make decisions relating to changing their heating system. With many different heat pump types and manufacturers available on the market with vastly different applicability, thermal output, installation complexity and cost, this app will help consumers confidently match the heat pump to thermal demand of the house and other specific needs on a case-by-case basis. The market at present often means that a consumer might be advised to get a heat pump from the manufacturer that the installer is more familiar with rather than what makes most sense for the home in question.

The surveyor app being proposed aims to properly size, efficiently monitor and optimise heat pump performance. At the moment there are a range of tools open to surveyors to undertake heat loss calculations for a home and this app is an attempt to move closer towards an easier, more standardized approach to calculating this. Finally, regarding apps they are also being produced for heat pump installers. The app would allow the installer to complete a digital survey and a fully automated design allowing for system optimisation from the beginning of the process. The platform would also ensure that all documentation is stored and logged against the installation, there will be full traceability for consumers and installers to access in the future when it comes to heat pump maintenance and service. Documents received by a consumer at handover of a heat pump can be extensive so having this in one place through an app could be very beneficial. The impact of this could facilitate a more streamlined installation process, significantly reducing the time and effort it takes to complete any installation. As well additional benefits could be derived from an installer app as it could store heat pump settings in order to benchmark for future maintenance and efficiency improvements whilst also acting as a training resource for new heat pump engineers. Better heat pump system design is being investigated through utilizing properties' smart meter data and low-cost sensors to directly measure key performance parameters on a property basis. The output from this is a publicly available protocol that defines the measurement options, standards that must be followed, what the outputs must comprise and how these should be presented. Finally standardised heat pump system design as part of a wider retrofit for non-traditional hard to treat homes is being considered.

In providing financial solutions to support wider heat pump deployment three key initiatives are underway. The purchase of a car through finance is a widely utilized financial product. Creating a financial product for the purposes of making the purchase of a heat pump more feasible by spreading out the upfront cost is being done as part of HPR stream 2. The Green Homeowner Loan aims to be financially attainable to help increase the sale of heat pumps and allow them to be a mainstream home purchase. Heat as a service is seen as another means to provide a financial solution to accelerating heat pump deployment at the lowest cost to the consumer. Consumers that buy heat as a service choose how much to spend on the experience they want – feeling warm and comfortable when and where they want in their homes – instead of paying for kilowatt-hours of energy [9]. Finally, the offer of a financially insurable performance guarantee to homeowners and landlords aims to use software integrated with existing retrofit supply chain components to quality assure quality design and installation of a heat pump system. This may be able to assist with ensuring installations are of good quality.

To address improving the consumer journey through the transition to heat pumps a number of data utilization initiatives amongst others are being delivered. The power of data clearly has a role within this area across surveying homes, heat pump installation, optimization and maintenance. Across these points of the consumer's heat pump journey projects are looking into smart meter data enabling better thermal modeling of the home to support accurate heat pump sizing and type suitability for a home. Installers can then obtain data of a heat pump system they've installed post-install to support their own learning. Housing associations responsible for heat pumps across a portfolio of homes might be interested in the ability to undertake remote reading of error warning messages from a heat pump to alert and enable a response to a heat pump performance issues. Heat pump system design is being considered through a digital solution to improve the customer journey by streamlining the required pre-installation steps into one remote survey reducing the amount of information required upfront ahead of an installation. The end-to-end digital solution could support customers in identifying innovative heat pump solutions, tailored to their profile. Other project offerings under this category objective include the ability to select MCS certified installers, filtering by name, type and location to obtain quotes. This would save the consumer considerable time in identifying an installer in what has been a difficult task due to a lack of installers in certain geographical locations.

In supporting the creation of a smart home energy system an output from the projects is to utilise smart meter data to embed heat pumps within a Home Energy Management System to optimize energy-related behavior within the home including renewable energy technology usage. This might involve for example accessing flexibility markets. Optimised energy management is also being considered through a platform that underpins advanced time-shifting strategies alongside proprietary artificial software intelligence software. This would take place through the use of machine learning for dynamic predictive modelling of energy requirements based on their patented sensing technologies. Finally, the potential for demand side management is being looked at through a heat pump and energy storage system combining energy recovery from the wastewater streams leaving a house. This will be done by drawing energy from the household wastewater stream by re-using energy lost, e.g. from the shower or bath, by fitting the heat pump in the drainage system to recover energy stored in a hot water cylinder.

5. Conclusions

This paper has showcased the high-potential innovative tools and technologies being developed under stream 2 of the HPR programme addressing barriers to domestic heat pump deployment across the five thematic areas. The paper has also considered the potential impact in supporting the deployment of heat pumps across the UK and in countries with similar climates and housing archetypes. The rapid evidence assessment undertaken during programme design highlighted the need for further trials and development of heat as a service to increase consumer understanding. HPR is directly addressing this through a heat as a service project and will obtain learnings on this. Similarly understanding the impact on the electricity grid of high-density heat pump deployment will be facilitated through stream 1 deployment as well as potentially better understood on how to mitigate this through the Kensa project. Effective coordination between heat pump stakeholder groups is being well tackled through the various apps being produced under stream 2 of which all are outlined in this paper. Finally the potential areas where research and innovation are listed under the rapid evidence assessment as being of significant benefit includes design improvements of heat pumps, manufacturing, installation, monitoring, maintenance and operational. The rationale for interventions in these areas are to address the performance gap between theoretical and actual heat pump performance. The ICAX, Ventive and Thermoelectric Conversion Systems projects should all provide interesting insights into improving heat pump manufacturing.

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