# **STRATEGIC RESEARCH AND INNOVATION AGENDA FOR HEAT PUMPS:**

Making the technology ready for mass deployment









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•3D - Three Dimensional •AI – Artificial Intelligence •AM - Additive Manufacturing •DH – District Heating •DHC – District Heating and Cooling •DHW – Domestic Hot Water •EC – European Commission •EPBD - Energy Performance of Buildings Directive •EPR - Extended Producer Responsibility •ESCO – Energy Service Company •EVs – Electronic Vehicles •GDP – Gross Domestic Product •H&C – Heating and Cooling •H&CS – Heating and cooling as a service •HP – Heat Pump •HpA - Hecto pascals •HVAC - Heating, Ventilation and Airconditioning •IOT – Internet of things •LCA - Life Cycle Assessment •OSS - One Stop Shops •PnP - Plug and Play •PV - Photovoltaic •RES – Renewable Energy Sources •RHC – Renewable Heating and Cooling •SET – European Strategic Energy Technology Plan •SME – Small and Medium Enterprises •SPF - Seasonal Performance Factor •TRL - Technology Readiness Levels •UI - User Interface

•UX – User experience

## **1. FOREWORD**



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G reenhouse gases are rising at the global level and even our ambitious goal of net zero emission by 2050 would not save us from the severe consequences of climate change in the coming decades. We already witness more frequent droughts, floods, heat waves and in general more extreme climatic conditions around the world.

Adaptation to climate change is the inevitable path to diminish the immense socioeconomic consequences of the global emissions. When health and well-being of billions of people is on stake, we must think and act strategically and innovatively. We have a limited time and resources for climate change adaptation and we must use the potential of all the renewable technologies that have been gifted to us during our long journey of research and innovation.

Heat Pumping technologies use relatively simple thermodynamic cycles to exploit the low temperature renewable heat sources and consequently provide efficient heating and cooling services for building and industries. When it is combined to renewable electricity technologies such as Hydropower, solar PV and wind, it has a potential to provide fully renewable heating and cooling a mass scale. The technology itself is relatively mature and widely used in many locations such as Nordic countries. However, there is still a lot to do to remove the techno-economic barriers for mass market deployment of the heat pump technology at the global level. We need a System of Systems perspective to be able to cope with the growing complexity of the challenges ahead. To unleash the full potential of heat pump system, we need to think beyond the box of the technology itself. The research and innovation agenda should connect heat pumps to the other parts of the system to meet the ultimate goal of a whole. As heat pumps couple heating, cooling, and electricity sectors, inter- and trans-disciplinary research plays a pivotal role in harnessing the potential of the technology in different contexts. Heat pumps can offer demand flexibility in the future smart grids; they can interact with solar PV, electric vehicles and wind turbines at building, district and city levels to ultimately maximize the share of renewables and minimize CO2 emissions; they can simultaneously meet the heating and cooling demand in the neighborhood; they can utilize the waste heat in the industrial processes and provide more efficient heat for non-space heating purposes such as drying, cleaning, food processing, etc. Choice of refrigerant for any of those applications should follow a complex multi-criteria decision making process where tradeoffs between conflicting objectives should be considered.

This report briefly presents a non-exhaustive list of the "topics" that can be included in the Strategic Research and Innovation agenda for heat pump technologies. Stopping or at least slowing down the destructive machine of climate change requires well-defined and far reaching research, innovation and implementation plans and missions. Considering our limited time and resources, instead of reinventing the wheel, let's put more effort on removing the socio-techno-economic barriers in exploiting the huge potential of the existing sustainable and efficient solutions such as heat pumps. Synergies in different sectors can be found and the wealth of untapped innovation opportunities can be hopefully realized. The future will be more sustainable and brighter if we think and act more strategically and beyond the competing "technology boxes".

# 2. STATE OF THE ART, TRENDS AND TECHNOLOGY OUTLOOK

A heat pump allows the upgrade of energy from a low temperature level (heat source) to a higher one (heat sink). Several heat pump principles exist. The one most dominant in the market, the electric vapour compression cycle is based on the evaporation of a refrigerant and its subsequent compression. Heat transfer is taking place through heat exchangers. HPs are differentiated both by the heat source and the heat sink used. The heat source can be air, water or ground and can be of renewable origin or from waste/excess energy. Heat sinks are air or water and the energy is further distributed to buildings and processes through fan-coil units, radiators and underfloor/wall heating.

In the vapour compression cycle, an electric or thermally driven compressor is used. It requires driving/ auxiliary energy to function. Latest heat pump iterations can reach operating efficiencies (seasonal performance factor - SPF) of three to five. One unit of drive energy is transformed to three to five units of heat/ cold as per reversibility and multiuse of the technology. While heating heating pumps provide heating and hot water to approx. 11% of all buildings in the EU<sup>W</sup> , refrigerant cycle based solutions are the predominant technology for space cooling in the EU, with an estimated 40+ million HPs (increase of 12.6% of the HP market between 2018 and 2019) installed<sup>2</sup>. HPs are the only technology able to provide space Heating, Cooling and Domestic Hot Water (DHW), with all three services in one integrated unit.

The efficiency of the systems depends on the temperature difference between the heat source and the heat sink, the design of the system including its heat distribution, the efficiency of its components and the quality of installation. Given that HPs are emission free at the point of operation, the energy used and the way it is produced (e.g., renewables), coupled with this efficiency and constant improvements, can point to a significant reduction in greenhouse gas emissions. If green electricity is used, a near to completely emission free system is possible.

To develop the key Strategic Research and Innovation Agenda for Heat Pumps, a brief look into the existing state of the art, the existing trends (technology, market, political and social), as well as the technology outlook for the sector is needed, to inform the Life Cycle Assessment (HP LCA), namely:

#### STATE OF THE ART RESEARCH AND IMPROVEMENTS

Research and improvements are taking place all along the value chain of HPs, by the testing and deployment of new materials, component, refrigerants and operating ranges. Design, taking advantage of advancements in computing power and design, Artificial Intelligence and learning algorithms, Internet of Things and connectivity, as well as sector coupling with other innovative technologies, has put HPs at the centre of the green transition revolution.

#### **TECHNOLOGY TRENDS**

As per Modularity, Circularity, three-dimensional (3D) printing, Digitalisation of interfaces, design and monitoring, as well as ease of troubleshooting and repair, making the technology ready for mass deployment.

#### **MARKET TRENDS**

Building upon the transition to green energy sources as well as renewable heating and cooling, with prices expected to fall both due to mass production (and new manufacturing techniques) as well as CO2 taxation and incentives (e.g., national subsidies), mean that European heat pump sales grew by 17.7% in 2019 – the fourth double-digit growth in a row. With 1.49 million units sold across Europe yet a new sales record has been achieved. Assuming a life expectancy of approximately 20 years, the current European heat pump stock amounts to 13.27 million units, with this trend set to continue.<sup>3</sup>

#### **POLITICAL TRENDS**

A large emphasis has been put on net zero emission targets as well as a green recovery made with targeted EU, National and Regional investments. Supply chain resilience, local manufacturing and research, as well as upgrading and certifying the skills and competencies necessary all along the value chain of the sector, gaining rapid acceptance.

#### SOCIAL/CONSUMER TRENDS

As end users become aware of the efficiency, economic, environmental and health benefits of HPs, steps are being taken into making the installation, maintenance

<sup>&</sup>lt;sup>1</sup> Stats.ehpa.org. Accessed 2.4.2021

<sup>&</sup>lt;sup>2</sup>"Heat pumps barometer 2020 | EurObserv'ER." file:///Users/dan/Downloads/EurObservER-Heat-Pumps-Barometer-2020-en-20201125.pdf. Accessed 9 March 2021.

<sup>&</sup>lt;sup>3</sup> European Heat Pump Market and Statistics Report 2020, by the European Heat Pump Association.

and upgrading as standardised and efficient as possible. Innovations such as: Heating and Cooling as a Service (H&CS), Pre-emptive maintenance, One Stop Shops (OSSs), ensure ease of purchase, servicing and monitoring.

#### **HP FUTURE OUTLOOK**

Innovative business models, that are tested and verified under real life conditions, have made the application of HPs, not only possible, but preferable in a multitude of diverse settings and conditions (e.g., large application potentials have been recognised particularly in the food/farming, supply chain logistics/storage, paper, metal, and chemical industries, especially in drying, pasteurising, sterilising, evaporation, and distillation process.<sup>4</sup> With large commercial properties, including hotels and restaurants, universities, apartment buildings and health-care facilities, all benefiting from the technology).<sup>5</sup>

### **3. KEY PERFOMANCE INDICATORS:** THE SET-PLAN TARGET

The European Strategic Energy Technology Plan (SET Plan) is a key stepping-stone to boost the transition towards a climate neutral energy system through the development of low-carbon technologies in a fast and cost-competitive way. By improving new technologies and bringing down costs through coordinated national research efforts, the SET Plan helps promote cooperation among EU countries, companies and research institutions, and in so doing also deliver on the key objectives of the energy union.<sup>6</sup> Its structure being composed of specific actions, the particular activities and targets associated.

In this regard, of particular interest to HPs, are the following actions:

a) SET PLAN ACTION 4: Increasing the resilience and security of the energy system;  $^7$ 

b) SET PLAN ACTION 5: Energy efficient solutions for buildings;  $^{\rm 8}$ 

c) SET PLAN ACTION 6: Continue efforts to make EU industry less energy intensive and more competitive. <sup>9</sup> With the related activities and targets below:

No.	Activity	Target
1.	Reduction of return tempera- tures in current DH networks	<ul> <li>Develop suitable models for integrating heat pumps on different levels of the DH network to enable the decrease of local/global temperatures on a central/decentral location;</li> <li>Heat pumps to contribute to increasing efficiency of networks on the pri- mary side (&gt;10%);</li> <li>Heat pumps to contribute to decreasing return temperatures on the building side so that the efficiency of the connecting systems is increased (&gt;10%).</li> </ul>
2.	Optimised low temperature and highly flexible (micro) DHC networks	<ul> <li>Develop design solutions considering central or decentralised heat pumps and the integration of cooling options and storages to improve the utilisation of local solutions for heating and cooling services on various temperature levels, e.g., heating, DHW, cooling;</li> <li>Heat Pumps to contribute to climate goals by taking part in enabling a high level of utilisation of local energy sources (&gt;80%).</li> </ul>

<sup>&</sup>lt;sup>4</sup> High Temperature Heat Pumps: Market Overview, State of the Art, Research Status, Refrigerants, and Application Potentials 2018, by Arpagaus, Cordin; Bless, Frédéric; Uhlmann, Michael; Schiffmann, Jürg; and Bertsch, Stefan, "High Temperature Heat Pumps: Market Overview, State of the Art, Research Status, Refrigerants, and Application Potentials" (2018). International Refrigeration and Air Conditioning Conferen ce. Paper 1876.

<sup>&</sup>lt;sup>5</sup>New Heat Pump Models Boost Efficiency The state-of-the-art product line from Lochinvar is designed to improve energy performance in large commercial projects, by Greg Isaacson, 15th July 2020.

<sup>&</sup>lt;sup>6</sup>Strategic Energy Technology Plan (published 16th July 2014 and last updated 5th January 2021): <u>https://ec.europa.eu/energy/topics/</u> technology-and-innovation/strategic-energy-technology-plan\_en

3.	Optimised planning, manag- ing and monitoring of inte- grated regional energy sys- tems	• Develop guidelines, tools and methods on collection, processing and storage of energy data to monitor and forecast, for instance, the flexibility that heat pumps can provide to the electrical system.
4.	Cost-efficient, intelligent, flexible heat pumps (also thermally driven) and heat pumps for high tempera- tures	<ul> <li>Reduce costs for small and large size heat pumps by 50% (compared to 2015 market price);</li> <li>Develop prefabricated, fully integrated 'plug in and play' hybrid/multisource heat pump systems and integrated compact heating/cooling plants based on modular heat pumps.</li> </ul>
5.	Multi-source DH integrating renewable and recovered heat sources, higher temper- ature District Cooling and op- timisation of building heat- ing system, to minimise the temperature levels in district heating networks	<ul> <li>Contribute to the Increase amount of renewable heat by 25% cost effectively and without decreasing the service provided to consumer;</li> <li>Increase efficiency of heat pumps and chillers by at least 2% per degree Celsius by increasing at the same time District Cooling temperatures.</li> </ul>
6.	Develop suitable models for the efficient usage of close to zero cost electricity via boilers and heat pumps in combination with short and long-term storage solutions	<ul> <li>Successfully using multi-source DH will result in phasing out of fossil fuels and reduce the need for primary energy sources;</li> <li>Optimising system operation necessitates new competencies which are a possible area to create new, green jobs.</li> </ul>
7.	Heat pumps and refrigera- tion converting low grade heat or cool into higher grade heat or cool	<ul> <li>Successfully using multi-source DH will result in phasing out of fossil fuels</li> <li>Maximise the recovery of industrial excess heat/cold in a cost-efficient manner;</li> <li>By 2025, develop and demonstrate (to TRL 8) solutions enabling small and large, industries to cost effectively reduce their energy consumption by 5% by cost effectively upgrading excess heat / cold for more valuable application elsewhere in the process.</li> </ul>

<sup>&</sup>lt;sup>7</sup> Strategic Energy Technology Plan Implementation Plan Final Version – 15.01.2018. Temporary Working Group 4 Increase the resilience and security of the energy system

<sup>&</sup>lt;sup>8</sup>Strategic Energy Technology PLAN Temporary Working Group 5 on Energy Efficiency Solutions for Buildings Implementation Plan

<sup>&</sup>lt;sup>9</sup>SET-Plan ACTION n°6 - Implementation Plan – Endorsed 27/09/2017 "Continue efforts to make EU industry less energy intensive and more competitive"



# 4. RESEARCH PRIORITIES AND TOPICS FOR THE HEAT PUMP SECTOR

he Research priorities and topics are based on a Heat Pump Life Cycle Assessment (HP LCA) and have been developed with the assistance of the EHPA Research and Innovation (R&I) Committee, the RHC HP TP and the EHPA members. An LCA represents "an environmental management tool, which can be used to evaluate the impact of a product, a system, or an activity on the environment<sup>"10</sup>, but can also serve to analyse a certain device and the choices that were made in several areas (e.g., design). Note that, an LCA "is a cradle-to-grave or cradle-to-cradle analysis technique to assess environmental impacts associated with all the stages of a product's life, which is from raw material extraction through materials processing, manufacture, distribution, and use",<sup>11</sup> but this paper will not touch upon all these aspects (e.g., the extraction process for raw materials, distribution from a transport and CO2 emissions standpoint). And that gouvermental green procurement policies, also utilise the LCA approach, as per understanding of the whole lifecycle of goods and services being acquired from

resource extraction through to disposal, including the total cost of ownership, the relevant risks and opportunities, the environmental and economic costs or benefits to society, and any environmental or economic non-monetized positive or negative impacts to society.<sup>12</sup>



## 4.1. DEMAND (FROM THE END USER PERSPECTIVE)

Exploring the demand of a particular product, system or set of services, and the factors associated with the decisions of end-users/consumers, will prove essential in informing policy makers, HP component manufacturers, HP manufacturers, HP testing facilities and other relevant stakeholders in the decisions they will take. These decisions will be related to the tools to be used (e.g., communication channels), financial investments and support (e.g., extra public funding, innovative private business models), their proven potential in diverse mediums (e.g., pilot sites) and the timeframe in which such decisions are taken. As such, this section will explore, how and why user perceptions are important for HPs and any other RES/RHC technology, what are the communication strategies used and why, as well as how such factors influence the economics of the sector.

<sup>&</sup>lt;sup>10</sup> Life Cycle Sustainability Assesment for Decision-Making – Methodologies and Case Studies 2020, pages 95-124, Authors: Sheng Yanga, Kebo Ma, Zhiqiang Liu, Jingzheng Ren, Yi Man.

<sup>&</sup>lt;sup>11</sup> Environmental Management – Science and Engineering for Industry 2017, pages 57-75, Authors: Iyyanki V. Muralikrishna, Valli Manickam

<sup>&</sup>lt;sup>12</sup> Government of Canada: Policy on Green Procurement, Date modified: 13.06.2018, <u>https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=32573</u>

### 4.1.1. USER PERCEPTION (NEW BUILDINGS, RENOVATION, INDUSTRIAL) RETAINING TO AFFORDABILITY AND EASY SELECTION OF COMPATIBLE DESIGNS OF HEAT PUMPS

#### **OBJECTIVE**

End user/consumer perceptions are vital to the adoption of RES and of the HP technology and systems, ultimately representing the demand for such products and services, giving manufacturers valuable input and data and indicating the current and future market trends.

#### **CURRENT STATUS**

Understanding and researching the perception and information wanted/given to end users, is a task undertaken by several projects (e.g. <u>ENABLE.EU; C4ET;</u>

<u>COME RES</u> or <u>REScoop MECISE</u>). Such projects, complement the other steps of the LCA, by informing all relevant stakeholders on the appropriate choices, investments, training, skills of staff, ways of conveying information etc., needed to address the user preferences in the most suitable way and to increase the share of their particular product/technology on the market. A note must be made, that the users and their perceptions are constantly changing due to a myriad of factors and that a constant study and analysis of associated factors is required.

#### **KEY ACTIONS**

The key actions can be split into several parts:

- User centred approach (focusing on the users and their needs/perceptions);
- Combined academic (focusing on a combined approach of users and experts in the field, engaging in a dialogue);
- Combined all along the value chain (focusing on inputs from all along the value chain, that inform and influence the end user);

• Private and Public research and analysis. A key distinction must be made between market studies (mainly conducted by private companies) and user perception studies (mainly conducted via EU funding and by private organisations/NGOs). This is in part due to their differing purposes (informing market decisions or informing policy makers) and in their status in terms of information sharing (ones have commercial confidentiality and the others are freely sharable).

#### **TYPE OF ACTION**

This topic is a mix between research (e.g., focus groups, surveys of end users), innovation (in terms of new tools and process to study and quickly adapt to user needs and perceptions) and demonstration sites (where users can be shown and interact with the technologies /devices as to form an informed outlook).

#### RESULTS

The studies, conducted with a representative share of stakeholders, while considering a multitude of factors (e.g., economic, social, geographical) offer an up-todate glimpse into the drivers of individual and group environmental choices or the lack of such preferences.

#### LINK TO POLICY FILES

Informing end-users about options to decarbonise their energy systems and heating and cooling in particular is taken up in the EPBD and in the Renovation Wave Communication.

## 4.1.2. COMMUNICATION STRATEGY (NEW BUILDINGS, RENOVATION, INDUSTRIAL) ON COMFORT, ENVIRONMENTAL IMPACT AND FINANCIAL ANALYSIS OF HEAT PUMP INVESTEMENT



#### **OBJECTIVE**

A clear communication strategy is vital to the dissemination of up to date, relevant and targeted (to the particular stakeholders) of key messages and results relating to the advantages of installing HPs. Ultimately, leading to the mass deployment of HPs, that not only accomplishes the objectives for the energy transition laid out by the EU, but also decreases the price and acceptance of HPs (a self-supporting action).

#### **CURRENT STATUS**

Buildings (and the people living inside them) are the first consumers of heating and cooling in the EU, closely followed by industry. Despite being different sectors, they share a common problem: there is still resistance towards an energy-efficient renovation of their heating and cooling systems.

The reasons suggested as to why the resistance is still a reality are such as: a lack of awareness of the benefits, lack of information on actual energy consumption and costs, the lack of advice on the technical possibilities and the lack of information of the different resources available.

#### **KEY ACTIONS**

Several actions should be considered to raise awareness on the importance of an energy-efficient renovation of heating and cooling systems:

• To target bodies such as consumer associations, to advice directly consumers about efficient forms of heating and cooling;

• To work with local authorities in the design of the

TYPE OF ACTION

Research (get to know the target groups to approach to craft messages that are relevant to them, explore other actions that have been taken before to understand what can work and in what particular circumstances). Innovation (in terms of messages crafted, touch points with end-users), or in the delivery of the message and its appeal (e.g., gamification, social media compatibility). promotion strategies to address fragmented markets;

• To provide direct guidance for companies in identifying cost saving opportunities;

• To improve the frequency of metering and billing information for consumers to understand their real time consumption.

#### RESULTS

On a first stage (raising awareness stage):

- End users aware of the existence and benefits of HPs; Afterwards, combined with other actions that are not only communication related:
- End users interested in an energy-efficient renovation of their energy system;
- End users investing in an energy-efficient renovation of their energy system.

## LINK TO POLICY FILES

Informing end-users about options to decarbonise their energy systems and heating and cooling in particular is taken up in the EPBD and in the Renovation Wave Communication.

## 4.1.3. DEMO SITES (NEW BUILDINGS, RENOVATION, INDUSTRIAL) THAT SHOW HOW HEAT PUMPS CAN BE COMPLEMENTED WITH PV AND EVEN EV'S IN DESIGNING SYSTEMS

#### **OBJECTIVE**

Demo sites/technology demonstrators are an intricate part of EU funded projects. They showcase live operating conditions, the technology, its advantages (e.g., energy savings, cost savings), characteristics (e.g., comfort, predictability), as well as how HPs interact and improve upon a system.

#### **CURRENT STATUS**

New types or upgraded/improved iterations of HPs are part of demonstration sites all over the world. They are monitored to showcase their performance and durability, assessed against competing fossil fuel-based technologies and in diverse geographical and climatic conditions. Some project examples include: <u>REWARDHeat, Heat4Cool, SunHorizon</u>

#### **KEY ACTIONS**

There are several key actions and results that arise from such type of pilot implementation:

• The new technology is showcased and integrated into an RES system;

• Current HPs are improved upon and the efficiency gains are highlighted;

• Implementing pilot sites in diverse geographical (e.g., diverse RES resources, urban/rural), climatic, economic (e.g., difference in GDP per capita adjusted for purchasing parity) and sectoral (e.g., agricultural, renovations, EVs) circumstances, proves their versatility.

#### **TYPE OF ACTION**

Though this action serves Research and showcases Innovation, the most important goal of it, is to demonstrate the technology and associated benefits.

### LINK TO POLICY FILES

The importance of linking and integrating different technologies in one building is highlighted in the EU Strategy for Energy System Integration. The Renovation Wave Communication puts forward an integrated renovation approach, where buildings are transformed from consumers to producers of energy. Heat pumps play a key role in these projects since they enable a combination of high energy efficiency, reduced energy costs, integration of electric transport and systemic benefits for the stability of the grids.

#### RESULTS

Depending on the objectives of the project in which the HPs are deployed, results can include (based on the three projects exemplified above):

- Cost-effective solutions for DHC systems, which can satisfy at least 80% of the energy demand of the system with locally available renewable energy and waste heat sources;
- Demonstrates an easy to install and highly energy efficient solution for building retrofitting;

• Exemplifies that the HPs deployed are ready for the market and identifying the ultimate technical and non-technical barriers to be overcome before the commercialisation of the products in the short to medium time frame.



"Heat pump for combined heating and cooling in symbiosis with waste waster ground water and power" 2020 HPCY Decarbindustry Award winnining Project "Picture provided by TaarnbyForsyning

# 4.1.4 ONE STOP SHOPS (NEW BUILDINGS, RENOVATION, INDUSTRIAL)

#### **OBJECTIVE**

One-Stop-Shops (OSSs) are accessible advisory tools from the client perspective and new, innovative business models from the supplier perspective. It is a bridge between the fragmented supply side and the also fragmented demand side. They play the role of an intermediary point of contact valuable for both homeowners (1 contact point) and suppliers (easier to manage the transactions towards their potential clients).<sup>13</sup>

#### **CURRENT STATUS**

OSSs are a natural response to the many aspects associated with the energy transition (e.g., diverse companies and services involved) as well as the tools (e.g., financing) and examples available. With many such initiatives being started, or already running. An example is <u>SuperHomes2030</u>, which tries to scale up its already running deep retrofit services and ultimately expand its proven approach to other countries available.

#### **KEY ACTIONS**

OSSs are going to become more widespread, and they should be considered as essential (supported with funds) for the energy transition. As such, there are three important aspects relating to OSSs and HPs:

• OSSs give financial advice (e.g., subsidies) to offset the cost of a deep retrofit and can showcase the advantages of HP for the consumer;

• They offer first-hand examples of the use and integration of HPs with other RES and E/TS;

• OSSs enable the manufacturers and service providers of HPs to collaborate more closely and efficiently (both dealing with each other and the costumer).

#### **TYPE OF ACTION**

Though OSSs can contribute to research, as per gathering data on user preferences and the collaboration between stakeholders, they should be considered more of an innovation (for the sector) and of a demonstration of all the resources and capabilities available. Moreover, the service can easily link to a combined product offering (e.g., already linking HPs and electricity storage).

#### RESULTS

To achieve the renovation rate and mass deployment of HPs needed, OSSs should be implemented (based on prior projects that have developed a suitable approach and set of tools) at a local level in all EU countries. This will result in the end user receiving the best advice and support available.

### LINK TO POLICY FILES

EHPA recommends that both in the Energy Efficiency Directive and the Renewable Energy Directive, the EC should encourage Member States to put in place one-stop shops for information, advice, and funding of renovation to improve both the energy efficiency and the renewables share of the building with heat pump technologies. The requirements of these one-stop shops should be that renewable heating is put in place.

<sup>&</sup>lt;sup>13</sup>Boza-Kiss, Benigna; Bertoldi, Paolo; (2018). JRC science for policy report: One-stop-shops for energy renovations of buildings. European Commission. https://www.researchgate.net/publication/329362745\_One-stop-shops\_for\_energy\_renovations\_of\_buildings\_Case\_studies



## **4.1.5 INNOVATIVE BUSINESS MODELS**

#### **OBJECTIVE**

These topics are also covered in the main RHC SRIA; however, each technology has its own particular business case and part in the flexibility and sector coupling of the overall system. As per their goals, business cases (supported by data gathered in real life conditions) highlight the returns (be it economic, social, environmental) of a set of actions and technologies for diverse end users and scenarios (e.g., local governments, financial/investment institutions).

#### **CURRENT STATUS**

Current market conditions are always shifting towards the more efficient, cost effective and environmentally friendly alternative. As such, adding to the current business case for HPs, there are several business models that could arise from using the flexibility of residential heat pumps in a smart grid. While testing such innovative approaches is already being carried out in real live conditions.

#### **KEY ACTIONS**

In order to successfully apply business models that use heat pump flexibility:

- The connectivity of the heat pump unit is crucial, as well as tailored controls;
- Strategic partnerships between players in the power sector, as well as HP manufacturers and HP

operators should be encouraged;

- Technical aspects, such as the needed development of connectivity, data analysis and control algorithms should be enhanced;
- The influence of variable/diverse operating conditions should continue to be studied.

#### **TYPE OF ACTION**

Demonstrating the economic and environmental case for HPs in real life conditions via business models that are designed to provide accurate data for: revenue, costs, scale-up, investments, subsidies and financial sustainability.

#### RESULTS

Business cases showcase the technology and its economic benefits, while encouraging more private and institutional actors to take part in the deployment and scale-up of HPs. All these being highly adapted to the local, regional and national conditions, expectations and demand.

### LINK TO POLICY FILES

The Renovation Wave Communication highlights the importance of new business models: "The use of standardised industrial solutions applied as part of a comprehensive renovation package enable cheaper and quicker renovation with limited impact on the residents and can be of particular relevance in the case of social housing."

#### OBJECTIVE

**Sector coupling** refers to the idea of integrating the energy consuming sectors such buildings (H&C), transport and industry with the power producing sector. It can improve the efficiency and flexibility of the energy system as well as reduce the costs of decarbonisation.

**Flexibility** is the ability to increase or reduce the production of power plants or the consumption of demand processes.

#### **KEY ACTIONS**

It should be considered that the replacement of fossil fuels processes for electrical renewable processes has several consequences:

 More pronounced demand peaks and higher variability;

• The volume of less predictable generation becomes larger thanks to the increasing share of renewable energy sources.

#### **CURRENT STATUS**

There are several technologies available to decarbonise the energy demand for heating and cooling for sector coupling (using for instance direct use of renewable energy such as geothermal energy or via electrification of building heating systems with heat pumps).

Over the last years there have been several projects and initiatives that study the possibilities of sector coupling and flexibility.

Back in 2010, the project <u>eFlex</u> demonstrated that it was possible to reduce the peak load from 61% to 47% using EVs and heat pumps.

There are several barriers to sector-coupling:

- Some technologies are not yet competitive;
- Restrictive market conditions, with low fossil fuel prices compared to renewable alternatives.

#### **TYPE OF ACTION**

Demonstration and enhancement of the role HPs play in sector coupling and flexibility (from a technical, social and economic standpoint). As well as additional economic and environmental savings via a flexible tariff controller, that stores energy for when the electricity prices increase due to peaks. Examples include: Ovo energy (UK); Octopus (UK), Awattar (AT, DE), Switch / Eon (SE) or Tiko (CH)

#### RESULTS

Sector coupling can contribute to a cost-efficient decarbonisation of the energy system, by exploiting the potential of synergy and interaction between different parts of the energy system.

### LINK TO POLICY FILES

The EU Strategy for Energy System Integration focuses on sector coupling and flexibility. Also, the Electricity Directive and Regulation are key legislations regarding flexibility and flexible tariffs.

## 4.2 DESIGN 4.2.1 MODULARITY

#### **OBJECTIVE**

Modular products are those that fulfil various functions through the combination of distinct building blocks (modules). Modules enable manufacturing companies to customise a product by assembling various combinations of modules. Modular design involves creating different product variants based on the configuration of a defined set of modules.

Modularity enables the production of a large product variety/quantity while maintaining low costs. Manufacturers use modularity to produce modular components that can be shared with other products/ equipment, enabling mass-customization and laying the foundations for product and component standardization, as well as ease of service.

#### **CURRENT STATUS**

Modularity has been studied and showcased, with an example being, the <u>F3Factory</u> project which ran from 2009 to 2013, that aimed to design and apply plug and play modular and sustainable production technology that could be widely implemented throughout the chemical industry.

#### **KEY ACTIONS**

In order to boost modularity in the HP industry several elements should be considered:

- Establishing design guidelines and standards for modular production units;
- Designing spare parts or modules that can be compatible with different types of unit;

• Demonstrating modular production at industrial scale for both industrial and residential applications;

• Demonstrating ease of replacement/upgrading of modules (sustainability of product);

• Communicate the benefits of a modular approach.

#### **TYPE OF ACTION**

Demonstrating the economic and environmental case for HPs in real life conditions via business models that are designed to provide accurate data for: revenue, costs, scale-up, investments, subsidies and financial sustainability.

#### RESULTS

• High volume production of HP components and assemblies at a low price, while also potentially decreasing manufacturing time;

- Servicing and upgrading process is simplified due to availability of standard modules;
- Increase in the lifetime of HPs and adaptability.

## LINK TO POLICY FILES

Modularity is covered by Ecodesign lot 1, lot 2 and lot 10 that looks at the efficiency and includes standardisation of space heaters and water heaters products. This includes packages, hybrid systems and other combinations of products.

## **4.2.2 CIRCULARITY**

#### **OBJECTIVE**

Circularity lays its foundations in 3 principles: •Prioritise renewable inputs

- Maximise product use
- •Recover by-products and waste

In a circular economy resources are kept in use alleviating costs associated with extraction, transport and disposal, associated with linear design. Once their lifetime is over, materials are recovered, recycled and reused.

#### **KEY ACTIONS**

• Demonstrate HPs ability to recover and re-use waste heat for heating and cooling purposes;

- Recycle HP components and materials when HP unit lifetime has ended;
- Re-think design of HP components and parts (modular design, standard parts for easy reuse and servicing).

#### RESULTS

Reducing carbon and environmental footprints;
Increasing product energy and resource efficiency;
Increasing recycled materials in HPs.

#### **CURRENT STATUS**

HPs contribute to the circular economy in different ways, one of them being recuperating and using excess heat in diverse heating and cooling processes. This way, heat pumps link the use of renewable energy (such as waste heat) with energy efficiency. There are currently several initiatives that use waste heat for heating and cooling. An example is <u>REWARDHeat</u>, a project which aims to demonstrate that a new generation of district heating and cooling networks is possible by recovering renewable and waste heat, available at low temperature. Moreover, a real effort has been and is being undertaken by manufacturers to increase the circularity of components and materials used.

#### **TYPE OF ACTION**

Showcase HPs ability to recover and re-use waste heat for heating and cooling. Innovation in developing modular heat pump designs with easily replicable and upgradable modules/sub-systems.

## LINK TO POLICY FILES

Circular economy issues are addressed in the circular economy action plan, the Ecodesign and Energy Labelling Working Plan 2020-2024, the review of the MEErP and in the sustainable products initiative.



Gare Maritime, Brussels. Picture provided by Boydens Engineering.

## 4.2.3 HYPER EFFICIENCY

#### **OBJECTIVE**

1 1 4

Heat pumps have become increasingly important as a technology to reduce primary energy consumption and greenhouse gas emission. They currently represent a very efficient alternative to fossil-fuel-based heating and cooling, as properly designed and installed heat pumps can regularly attain more than 300% efficiency. Despite their high efficiency rate there is still room for developing more energy-efficient HP systems, with both incremental improvement and new approaches being rolled out continually.

#### **KEY ACTIONS**

- •Optimising the energy sources and sinks of HPA;
- •Minimising auxiliary drive powers;
- •Optimising HP temperature and capacity controls;
- •Deploying new materials, systems and approaches.

#### RESULTS

• High volume production of HP components and assemblies at a low price, while also potentially decreasing manufacturing time;

• Servicing and upgrading process is simplified due to availability of standard modules;

• Increase in the lifetime of HPs and adaptability.

#### **CURRENT STATUS**

Over the last years there have been several technical developments to improve the efficiency of HPs. In the context, <u>GEOTech</u> (Geothermal Technology for economic Cooling and Heating) project for example, a dual source heat pump was developed. The HP technology was tested in several demo sites where it was proved that it was a high efficiency as well as cost-effective alternative for H, C and DHW.

#### TYPE OF ACTION

Achieving hyper-efficiency mainly serves Innovation (such as finding ways to optimize HP temperature and capacity controls) and demonstration purposes (implementation of hyper-efficient systems in both industrial and residential contexts).



#### LINK TO POLICY FILES

The continuous efficiency improvements of HPs are covered by Ecodesign Lot 1, 2 and 10. The energy labelling legislation ensures that the efficiency of HPs is communicated to the public to ensure its mass deployment.



Grocery store of Kesko Oyj, Finland. Picture from 2020 HPCY Next Generation Heat Pump Award winning project "Energy recycling system for grocery stores of Kesko Oyj" provided by Tuomo Niemel ä.

## 4.2.4 EASILY CONNECTED TO OTHER TECHNOLOGIES & STORAGE MEDIUMS

#### **OBJECTIVE**

The wider implementation of variable renewable energy sources across the EU to reduce greenhouse emissions, demands interconnection, energy storage and more dynamic energy systems.

#### **CURRENT STATUS**

Nowadays there are several technologies available to decarbonise the energy demand for heating and cooling. Several projects have showcased in the last years that it is possible to provide renewable heating and cooling by combining those alternative and current / next generation renewable energy sources (DHC, PV, waste heat, Geothermal, Wind, Tidal, solar heat collectors, Aquathermal) with Heat Pumps as well as current / next generation storage (thermal, electrical). A few examples, include: <u>GeoAtlantic, DryFiciency, Heat4Cool, STORY</u> the circularity of components and

#### **KEY ACTIONS**

It should be considered that only replacing fossil-fuel-power heating systems by HPs can reduce carbon emissions by 35%-65%. HP technologies combined with green electricity (obtained by renewable energy sources mentioned above) has the potential to nearly decarbonise heating and cooling. It also should be highlighted that demand can be reduced up to 55% by improving the efficiency of the building envelope and it can be further reduced if the remaining energy demand is supplied by near zero emission technologies and energy sources. Hybrid systems that combine heat pumps as well as renewable energy sources are the best option for the optimisation of the demand.

#### **TYPE OF ACTION**

Demonstration (showcase the different applications and environmental benefits of using HPs in combination with other renewable energy sources).

#### RESULTS

materials used.

Replacing fossil fuels with renewable energy or using excess energy, results in decreasing demand, improved efficiency, cleaner air, as well as laying the foundation for moving towards zero emissions.

### link to policy files

The implementation of renewable energy sources is covered by the Renewable Energy Directive. In the EU Energy System Integration Strategy, the importance of integrating different renewable energy sources and solutions is highlighted.

## **3.2.5 HEALTH**

#### **OBJECTIVE**

• According to global statistics from the World Health Organisation (WHO), 9 out of 10 people breathe in air containing high-level pollutants. Poor air quality is today a huge risk to public health. Air pollution is mainly caused by vehicle transport, but there is a significant contribution system that burn fossil fuels to produce heat. • Most HPs contain air filters that can clean the air as it goes through, removing any potential allergens as well as deodorizing it. This is important if you have individuals in your household with allergies or sensitivities and if your pets are indoors. The filtration system will remove even the smallest of allergens and either break them down or neutralise them, to create a healthy comfortable home. • HPs prevent dwellings from being damp and cold (both of which are the perfect ingredients for unhealthy living). The WHO recommends a minimum inside temperature of 18 degrees Celsius, and even higher for households with young children or elderly (especially for those with respiratory illnesses or allergies). The way HPs contribute is by providing steady heat, as well as being affordable (less costs via heating bills equates to funds that can be used in other home improvements/renovations as well as improving overall standards of living).

#### **CURRENT STATUS**

• HPs themselves are electrically driven devices with no combustion, therefore, by themselves they pro-

duce no pollution in the place of heat delivery. However, it should be noted that there might be emissions derived from the structure of the electricity generation (however, as we are transitioning into green electricity, these are dropping as well). And that, implementation of climate-friendly, effective refrigerant fluids is already taking place.

• The sound perception of heat pumps is linked to the installation of the unit. Its location (city/countryside, outdoor/indoor, placement) and its surrounding environment (closed-room, other buildings...), its exposure and even its visibility. With new approaches (e.g., easy to use phone applications) that assist with placing HPs as to ensure that all factors are taken into account.

#### **KEY ACTIONS**

From the sound perspective there are several actions to be taken into account to enable HPs to make a positive impact on the end-users' health: • Installers should be provided with a guide outlining installation and placement parameters as well as commissioning tools for finding the ideal placement of the heat pump in the particular location; • A realistic and transparent marketing communication about the real sound emitted by heat pumps should be carried out (to match expectations of end-users with reality);

• Manufacturers should contribute on raising consumer's awareness of the health benefits of heat pumps and strive to improve them;

• The need for effective knowledge sharing between industry and general public (e.g., sound guide) should be addressed;

• Variety of heat pump design from an aesthetic standpoint.

#### **TYPE OF ACTION**

The actions to be taken in this topic serve research, innovation and demonstration purposes. It is vital to research what is perceived as noisy and how HPs components interact to reduce the noise they produce as well as for determining the perfect placement. Innovation should be carried out in the marketing strategy deployed, that highlights the health benefits in addition to the economical ones. The demonstration of the previous steps could be materialised on a guide for installers and information for both industry and the general public, that is easily understandable and quantifiable.

#### RESULTS

Highlighting the added health benefits of HPs as well as improving some of their aspects (by offering a variety of designs), will assist in the needed mass deployment and fossil fuel replacement drive.

### J

#### LINK TO POLICY FILES

General energy and climate benefits of heat pumps in comparison to fossil fuel heating systems are recognised in different EU legislations and communications. But there could be a stronger emphasis in EU legislation on the health aspect and the indoor environmental quality of HPs. In Ecodesign and Energy labelling legislation Lot 1, 2 and 10 information on the sound is being developed and will be displayed on the label in the future.



## **4.3.1 ADVANCED COMPUTER MODELLING** AND SIMULATIONS

#### **OBJECTIVE**

Energy efficiency of the built environment is crucially important for the better use of energy resources as well as the preservation of the environment. Reducing the environmental impact of the heat pump equipment requires the adoption of more energy efficient designs. These design challenges can be best met with the use of modelling tools.

#### **KEY ACTIONS**

It is vital that the simulation programmes are flexible, with the possibility of modelling different kind of systems and components as well as the possibility of adapting the model under certain particular requirements.

#### RESULTS

The use of computer modelling and simulations should aim at overcoming design challenges for creating more energy efficient designs.

#### **CURRENT STATUS**

Over the last two decades, there has been a development of simulation programs for the design of heat pump systems (<u>TRNSYS</u>, <u>MODELICA</u>, <u>EnergyPLUS</u> etc). The programs can be used in either of two computational modes:

- Simulation mode (simulate system performance)
- Design mode (calculate component design parameter value)

#### **TYPE OF ACTION**

**Research:** data provided by the simulation programs that allows to discover better design for energy efficiency of heat pumps, while running a multitude of tests in the virtual space allows not only to save resources on prototype construction, but also identifies and fixes any faults quickly and easily.

Innovation: new tools or improvement of the existent tools for a flexible and user-friend performance.

**Demonstration:** simulations that demonstrate the efficiency of design and performance of the heat pump system and its components.

### LINK TO POLICY FILES

There is no specific EU legislation on simulation programmes, but digitalisation and smart appliances in general is covered by Lot 33 on smart appliances.



## 4.3.2 MASS PRODUCTION & 3D PRINTING

#### **OBJECTIVE**

Three-dimensional (3D) printing, also known as Additive Manufacturing (AM) is a transformative approach of industrial production that enables the creation of lighter, stronger parts and systems. 3D printing is slowly becoming more and more important and is representing an alternative to conventional manufacturing technologies.

By adding material in layers while manufacturing complex components, components are stronger, and waste is avoided. By creating a range of different

#### **KEY ACTIONS**

• 3D printing provides a tool-less process free from manufacturing constraints and tooling costs;

• 3D printings' design freedom enables the implementation of optimised variable geometries;

• It is vital to increase the cost efficiency of the 3D printing of heat exchangers in order to be able

shapes, 3D printed components have an advantage in energy efficiency and system performance.

#### **CURRENT STATUS**

Recently, 3D printing has been used in several projects for the development of heat exchangers, mainly due to the design optimisation that the additive manufacturing's design freedom enables.

<u>Agent-3D\_AutoHeat</u>, for instance, aims to autonomously generate small, high-performance heat exchangers for specific applications and their adaptation to their individual boundary conditions and requirements.

to industrialise and scale their production successfully;

• It is crucial to understand which shapes promote energy efficiency and better system performance.

#### **TYPE OF ACTION**

Innovation: use of new tools for developing components adapted to different requirements, that have an advantage in terms of energy efficiency, system performance, or materials used.

**Demonstration:** possibilities of creating and demonstrating the efficiency of optimised components of heat pumps such as heat exchangers.

#### RESULTS

The adoption of 3D printing can result in the development of the next generation of thermal management systems that are adapted to specific applications and boundary conditions. It also allows to print certain components (for replacement/upgrading), close to the end-user, adverting transport, logistics and decreasing wait times.



### LINK TO POLICY FILES

There is no specific legislation covering this.

## **4.3.3 INTEGRATED CONNECTIVITY**

#### **OBJECTIVE**

The term "Integrated Connectivity" stands for the architecture of wireless connectivity devices.

HPs that can be remotely connected to other devices, such as smartphones or tablets, can be remotely controlled, updated, monitored and diagnosed remotely, as long as there is an internet connection (note that other types of wireless connections exist that do not involve the internet, but these are local/in close proximity and have the same use scenarios e.g., Bluetooth)

#### **CURRENT STATUS**

Not only do remotely connected systems such as Wireless Fidelity (WI-FI) allow to control the HP system from any location, they also enable to programme HPs to every user's specific needs, increasing comfort and even saving energy (minimum and maximum temperatures, times of operation, possibility of monitoring the temperature of a specific room), as well as to easily adapt and modify this programming.

There are currently several plug and play solutions present in the market that act as a bridge between the HVAC system and smart devices and enable the remote control of the heating and cooling system such as <u>Pebble Wifi</u> and <u>Wiheat</u>

#### **KEY ACTIONS**

While developing solutions that connect the HVAC system and smart devices, several elements should be taken into account:

• The design of the software tool used should be comprehensive and easy to use in order to improve the user interface (UI), by developing a set of visual keys that express each of the functions in an intuitive manner; • The development of measures to protect users from others (cybersecurity) using their HPs (such as bar codes usage or serial number introduction) as well as a way to easily monitor threats and update the software accordingly, should be widely deployed, as per the recommendations of the Common European energy data space. <sup>14</sup>

#### **TYPE OF ACTION**

Integrated connectivity tools such as WIFI controllers for heat pumps should be considered an innovation for the comfort of users, as well as a way to easily monitor and service the systems.



#### LINK TO POLICY FILES

The connectivity of HPs and other devices is covered by Ecodesign Lot 38. Also the Energy Performance of Buildings Directive includes an article on the Smart Readiness Indicator (SRI) to indicate how smart a building is.

#### RESULTS

A secure system that provides easy-to-use remote control for heat pump users and that enables energy savings, as well as a tailor-made heat pump use. With the ultimate goal of increasing the connectivity and capability of devices as well as comfort and energy efficiency (e.g., heating and cooling via a HP that starts operating when it detects the inhabitants of the dwelling are on their way home via connection with their EVs or via calculating the changes in distance to their smartphones)

## 4.3.4 STANDARISATION OF COMPONENTS AND CONNECTORS

#### **OBJECTIVE**

Standardisation is defined as the process of developing, establishing and implementing guidelines that enable the mass production of spare parts and components, which can be fitted into any equipment without any adjustment needed.

Standardisation could be considered a tool for the circular economy, as it encourages the service of equipment by simplifying the process of finding replacements for non-functioning subsystems.

Standardisation can also benefit manufacturing companies, as the mass production of spare parts suitable for several equipment (interchangeable) can reduce the cost of production and logistics (e.g., warehousing).

 $<sup>^{14}</sup>$  A European strategy for data, Brussels, 19.2.2020 COM(2020) 66 final



#### **CURRENT STATUS**

The process of standardisation has recently reached the high-level policy sphere in the shape of "right to repair" regulations on domestic appliances (<u>EU Commission ratified new "right to repair</u>") that will require manufacturers will be required to design and make spare parts which are easily and readily available for 7 to 10 years.

#### **KEY ACTIONS**

- Need for a regulation not only for the standardisation of domestic appliances;
- Use of advanced computer modelling to design components that can be used in different equipment without losing functionality.

### LINK TO POLICY FILES

Standardisation of HP systems and components is covered by the Ecodesign Directive. Improving the lifetime and re-using of components is covered by the Circular Economy Action Plan. Over the last years, the benefits of standardisation have taken shape in diverse sectors and with different initiatives and companies. An example being <u>SPEEDIER</u>, a project that applies and integrated approach to energy management and that has laid the foundations for the interoperability of their software tool to carry assessments on the energy saving solutions available for different SMEs.

#### **TYPE OF ACTION**

Innovation: design of spare parts, subsystems, connectors and other sub-assemblies, that can be mass produced and easily interchangeable.

#### RESULTS

Standardisation of components encourages the circular economy and makes servicing and maintenance easier by:

- Simplifying the servicing processes and, this way, extending products lifetime;
- Re-using components on different equipment;
- Improving logistics all over the supply chain, as well as decreasing training time needed for servicing personnel.

## 4.3.5 SUPPLY CHAIN RESILIENCE

#### **OBJECTIVE**

Supply chain resilience is the supply chain's ability to be prepared for unexpected risk events/disruptions and then being able to respond and recover rapidly in order to return to the original situation, or even expand by moving to a new, more desirable state, by increasing customer service, market share and/or financial performance.

#### **CURRENT STATUS**

As described by the IEA 2020 report (<u>Heat pumps</u> and other renewable energy are not immune to the

<u>Covid-19 crisis, but they are more resilient</u>), Covid-19 caused a risk of delay or cancellation to investments made by individuals and small to medium-sized enterprises for the installation of heat pumps on their property.

On the other hand, another IEA 2020 report (<u>Renewable energy market update- Analysis</u>) highlighted that in 2021, the majority of delayed projects are expected to come online, leading to a rebound of new installations, and demonstrating the resilience of the renewables sector.

#### **KEY ACTIONS**

In order to build supply chain resilience several elements should be taken into account:

 Crisis manual (definition of potential disruptions as well as description of support mechanisms and advice on messages and actions to overcome them);

• Manufacturing network diversification (applicable all along the supply chain, e.g., transport logistics);

• Nearshoring: development of regional or local supply chains to move the product closer to the end user and have better control over inventory;

• Standardisation of components simplifies sourcing policies and creates opportunities to place higher volumes among multiple suppliers, which enhances resiliency.

#### **TYPE OF ACTION**

**Research:** in-depth insights about the HP supply chain and the diverse parts associated with it, as well as analysis of possible risks, solutions and contingencies to overcome them.

Innovation: standardisation of components, discovering new ways to organize logistical/sourcing aspects to increase HPs supply chain resilience. itor and service the systems.

#### RESULTS

A supply chain not only able to recover from a disruption, but a supply chain that is able to grow from said disruption, is easily adaptable, sustainable and scalable.



### LINK TO POLICY FILES

On behalf of the EC DG ENER, a consultancy is carrying out a study on the resilience of the supply chain which are critical for energy security and the clean energy transition. The aim is to design short-term and long-term measures to address the possible challenges.

# 4.3.6 UPGRADING THE SKILLS OF MANUFACTURING PERSONNEL

#### OBJECTIVE

Continues changes in technologies and approaches, need to be met with the upgrading of the skills of personnel (all along the value chain). The goal of scaling up the use of green technologies (the mass deployment of HPs needed to meet policy and environmental goals) can only be met by people and organisations with the right set of skills to successfully implement and improve upon them.

#### **CURRENT STATUS**

A Research carried out on behalf of the Department for Business, Energy and Industrial Strategy of the United Kingdom (Heat Pump Manufacturing supply chain research project) highlights that the UK boiler manufacturing workforce has a complementary skillset to those in the HP manufacturing and remarks how crucial it would be for safeguarding employment and benefiting from existing skills to transfer the boiler manufacturing work force to the heat pump industry.

#### **KEY ACTIONS**

Despite the technology being different, many of the components and engineering of heat pumps are boilers are similar. Therefore, the upskilling of boiler manufacturers for HP manufacturing should be taken into consideration while transition from gas boilers to HP manufacturing. With one example, among many, being the <u>HP4All</u> project.

Additionally, the skills and competencies of staff all along the value chain of HPs, are vital as these professionals are the ones that the customer/end user interacts and seeks advice/information from.

#### **TYPE OF ACTION**

The most important goal is to demonstrate how the technology works and its associated benefits through the training of (already trained/re-skilling and up-skilling) professionals of the manufacturing sector. And to ensure that all HPs are installed and commissioned in the most efficient and suitable way.

#### RESULTS

The transition of trained professionals (from the boiler industry, for instance) to the manufacturing/installation/maintenance of renewable energy systems such as heat pumps is a key enabler for the mass deployment of the technology.

### LINK TO POLICY FILES

The European skills agenda covers all issues related to improving skills in the framework of the European Green Deal.



## 4.4.1 SKILLS CERTIFICATION AND UP-SKILLING OF INSTALLERS

#### **OBJECTIVE**

Installers are currently the market makers for many technologies. In contact with the customers, they should be able to provide a trusted service that matches the innovation of the technologies ready to enter the market.

The mass deployment is only possible through the up skilling of installers

#### **KEY ACTIONS**

Data from several markets in Europe indicate that a doubling of the European HP Market by 2024 is realistic. Therefore:

- Industry should prepare the value chain for the installation of a much larger number of units;
- · Constant new developments in the technology

#### **CURRENT STATUS**

Currently very few professionals have the required expertise in energy efficient construction and in efficient and renewable energy technologies. Initiatives such as <u>HP4ALL</u> aim at enhancing, developing, and promoting the skills required for high-quality, optimised HP installations within residential and non-residential European Buildings.

require the constant development of training and re-training;

• Better skills and knowledge in the installation process should be fostered to avoid concerns from other professional groups (such as architects) regarding HP technologies as well as to provide the most up-to-date information to the end user.

#### **TYPE OF ACTION**

Upskilling installers plays a major role on integrating the most innovative technologies in the market. Only upskilled installers are able to offer to the end user and implement the latest available, energy-efficient and renewable technologies such as HPs.

#### RESULTS

To achieve the renovation rate and mass deployment of HPs needed, skills certification should be vital. Trained professionals will be able to install HP technologies and provide the best advice and support to end-users.

#### LINK TO POLICY FILES

Both the Renewable Energy Directive and the Energy Efficiency Directive cover training and certification requirements for HP technologies.

## 4.4.2 PLUG AND PLAY SOFTWARE AND HARDWARE

#### **OBJECTIVE**

Plug and play (PnP) is a technology that allows a device to be connected to a computer without the need for physical device configuration or user intervention in solving resource conflicts. Plug and play applications on heat pumps simplify the process of installation.

#### **KEY ACTIONS**

Plug & Play systems applied to HPs in housing and small building sectors show:

• That it is possible to simplify the process of installation;

• HP's can be easier to operate once installed;

• There is room to develop plug & play systems for industry.

#### **CURRENT STATUS**

Some projects such as <u>GEOTeCH</u> have developed plug and play solutions for providing Heating and Cooling and DHW to housing and small building sectors. As for domestic use, these systems must be as compact and easy to operate as possible as well as reliable and automatic.

#### **TYPE OF ACTION**

This action serves research and displays innovation. Still, it is vital to demonstrate its implementation on HPs and its associated benefits.

#### RESULTS

Demonstrates an easy to install and to operate system that provide heating and cooling in residential buildings.

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### LINK TO POLICY FILES

The Renovation Wave Communication highlights the importance of new business models: "The use of standardised industrial solutions applied as part of a comprehensive renovation package enable cheaper and quicker renovation with limited impact on the residents and can be of particular relevance in the case of social housing."

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## 4.4.3 EASE OF INSTALLATION AND ADAPTABILITY TO LOCATIONS AND REQUIREMENTS

#### **OBJECTIVE**

The installation of HPs is a big investment for any homeowner and business. In order to ensure the efficiency of the HPs, it is vital to plan ahead and adapt the system to the demands of the end user. This relates to the skills and competencies of the installer, as well as to commissioning of the HP system once it is installed, to make sure it is operating within the manufacturer's specifications and the parameters initially planned.

#### **KEY ACTIONS**

• Development of pre-commissioning tools for simplifying the planning of the suitable HP system;

• Consideration of "fewer component" systems (such as plug and play systems) that can be adapted to any location.



#### **CURRENT STATUS**

Over the last years, there has been development on easy commissioning tools (F.e <u>PROCENTEC Commis-</u> <u>sioning Wizard</u>) that help commissioning engineers to easily determine baseline metrics for the HP system, while simplifying maintenance requirements.

#### **TYPE OF ACTION**

Research: data on performance of HP systems under different requirements/locations.

Innovation: development of tools for the design of HPs systems that are adapted to different requirements/ locations.

#### RESULTS

• Designing a system that matches the particularities of the location;

• A correctly installed HP ensures long-term efficiency and system health.

### LINK TO POLICY FILES

EHPA recommends that in the Renewable Energy Directive and the Energy Efficiency Directive, the EC encourages Member States to put in place one-stop shops for information, advice, and funding of renovation to improve the energy efficiency and the renewables share of the building with heat pump technologies. And to facilitate the installation and reduce the number of actors and administration involved.



## 4.5.1 EASY TO USE AND UNDERSTAND USER INTERFACE (UI)

#### **OBJECTIVE**

The UI is the graphical layout of an application. It consists of all the items the user interacts with while using an application. The aim of a good UI design is to provide user interface elements that turn the user experience (UX) into a smooth journey.

#### **KEY ACTIONS**

Despite our human ability to sense heating and cooling, like air, both are invisible. Therefore, several actions should be taken into account: • Development of a concept that makes visible the invisible;

- Development of "heat" and "cool" icons adapted to each context;
- Development of visual keys to express each of the functions that are easily to comprehend.

#### **CURRENT STATUS**

As devices' connectivity is integrating all facets of lives and, as the development of "unseen/out of sight" devices has expanded, the value of UX to stir user's emotions has drastically increased. Today, UI design plays a vital role on shaping the value of UX.

Recognising this, for instance, Daikin has incorporated the concept "visualisation of air" in applications. This guides the user in operating the device, due to the graphic images expressing each function.

#### **TYPE OF ACTION**

Even though research is needed for the creation of an easy-to-use UI, it should be considered mainly innovation to the sector as it implies adapting/upgrading the operation of the heating and cooling system to the age of device connectivity.

#### RESULTS

An easy-to-use and understand UI will mean, that end users enjoy a smooth User Experience while operating their HPs.

### LINK TO POLICY FILES

Everything related to smart appliances is covered by Ecodesign Lot 33 which is being developed.



## 4.5.2 INTERNET OF THINGS (IoT) DATA GATHERING AND CLOUD CONNECTIVITY

#### **OBJECTIVE**

The Internet of Things (IoT) is the process of using sensors to track the conditions of physical things. Those devices that are connected over the IoT are able to monitor, as well as measure data in real time. With data being relayed/transmitted, stored and retrieved at any given time and remotely.

#### **KEY ACTIONS**

The IoT adoption continues to escalate, and it should be considered as essential today. The integration of digital systems and the real time analytics can:

- Boost renewable power generation;
- •Reduce renewable power curtailment;
- However, several key factors should be considered:
- There is still room for reaching the complete

#### **TYPE OF ACTION**

It delivers to research as it monitors and measures data in real time. However, it should also be considered part of innovation and demonstration as it provides tools for optimising energy consumption.

#### **CURRENT STATUS**

IoT enables heat pumps to provide data that can be used for preventive analytics, such as what-if analysis for operation decisions, predictive maintenance, fine-tuning of the operation parameters and benchmarking, as well as to manage smart demand response to reduce the peak load and/or optimise electricity consumption as a function of the electricity price and integrating heat pumps in the building energy management (IEA HPT. (2016, October). Internet of Things for Heat Pumps. HPT.)

#### technology maturity;

- It is vital to make sure that data privacy is a reality;
- It is crucial to address cybersecurity challenges that might arise;

• There is a need for developing (secured) communication procedures and protocols.

#### RESULTS

IoT devices enable smart grids through the collection, transmission and use of data collected in real-time, this way optimising grid operation and increasing system flexibility, with smart HPs at the forefront of the effort.

## LINK TO POLICY FILES

The EC is developing legislative initiatives on data such as implementing acts on Data Access and interoperability, ePrivacy, and European Strategy for Data including Data Governance Act, Digital Service Act, Digital Markets Acts etc. Finally, the EC is also developing a Common European Data Spaces and Clouds Infrastructure.

## 4.5.3 ARTIFICIAL INTELLIGENCE (AI) ALGORITHMS FOR OPTIMIZATION

#### **OBJECTIVE**

Artificial Intelligence solutions, tie data from different sources together in order, for instance, to predict and prevent malfunctions before they happen and optimise this way the timing of maintenance, while improving the design of HPs to make them more efficient.

#### **CURRENT STATUS**

There are currently several projects/initiatives running using AI on heat pumps, one of them, on the Swiss Federal Institute of Technology in Lausanne in which, with the help of AI, they are developing heat pumps that consume 25 percent less electricity.

#### **KEY ACTIONS**

• It is vital to consider the commercialisation of the technology: think about the industrialisation process to make AI operating/maintenance algorithms available.

• The production/logistics of millions of heat pumps requires re-designing for mass-production, a sector where AI and automation can play a key role.

#### **TYPE OF ACTION**

Al contributes to innovation by optimising operation and thus making heat pumps more efficient. While actions and policy are adapted to mitigate any potential concerns related to the technology.<sup>15</sup>

#### RESULTS

The mass deployment of more efficient heat pumps can contribute to the decarbonisation of heating and cooling.

### LINK TO POLICY FILES

The EC is developing legislative initiatives on data such as implementing acts on Data Access and interoperability, ePrivacy, and European Strategy for Data including Data Governance Act, Digital Service Act, Digital Markets Acts etc. Finally, the EC is also developing a Common European Data Spaces and Clouds Infrastructure.

# 4.5.4 SOFTWARE UPDATES AND REMOTE DIAGNOSTICS (PREDICTIVE MAINTENANCE)

#### **OBJECTIVE**

Over the past few years HVAC services have shown increasing growth in remote diagnostics and fault detection. These allow the supplier/manufacturer to monitor the operation and health of the system and to provide detailed reports on maintenance and other adjustments (optimisation).

An effective remote diagnostic and monitoring tool, that is in constant contact with the HVAC system and is able to provide the most relevant key performance indicators and insights necessary to reduce costs and optimise maintenance programs would benefit, not only the end user, but the manufacturer and supplier, at the same time.

#### **CURRENT STATUS**

In the past, maintenance services used to be mainly corrective (fail and fix) or preventive. The increase of intelligent and responsive systems and approaches (IoT) has enabled more flexible and intelligent maintenance operations that can instantly detect indicators of failure, laying the foundations for predictive maintenance.

#### **KEY ACTIONS**

With the collection of real time data, remote diagnostics open the door for the smart maintenance of HVAC systems. Smart maintenance enables:

• The increase of productivity as it is possible to prevent any downtime and ensure operations to continue;

• The reduction of maintenance costs as adjustments will be predicted;

• The extension of the equipment's lifetime due to the combination between clear insights into

the condition of the system and a well-scheduled maintenance;

• The increase of energy efficiency of the system through the collection, transmission and use of data collected in real-time this way optimising grid operation and increasing system flexibility. As well as using and analysing the data as to inform future HP designs (potentially specifically adapted to a particular region and its climate).

<sup>&</sup>lt;sup>15</sup> Report on the safety and liability implications of Artificial Intelligence, the Internet of things and robotics, Brussels, 19.2.2020 COM(2020 64 final



#### **TYPE OF ACTION**

Remote diagnostics deliver to research as they monitor and measures data in real time. However, the use of remote diagnostics for the implementation of predictive maintenance should also be considered part of innovation and demonstration, as it provides tools for extending the life of the HVAC systems and optimising the energy consumption.

#### RESULTS

An effective remote diagnostics and monitoring can provide the most relevant key performance indicators (KPIs) and insights necessary to reduce costs and optimise maintenance programs.

### LINK TO POLICY FILES

The connectivity of HPs and other devices is covered by Ecodesign Lot 38.

## **4.5.5 EASY TO UNDERSTAND STATUS REPORTING**

#### **OBJECTIVE**

As vital as it is to have real time information about the status of the HVAC system for its correct operation, it is also crucial that the reports of status are understandable and comprehensive. During the operating life of the system good and complete report of status should cover planned and unplanned maintenance activities from electronic planned maintenance to on-site logbooks.

#### **KEY ACTIONS**

Status reporting should aim for the maximum clarity. In this sense, there are several elements that should be taken into account:

• The importance of including standard recommendations for maintenance activities;

• The importance of including visual insights (convey data in a visual way);

 The ease of sharing data between platforms and stakeholders.

#### **CURRENT STATUS**

As indicated by SEAI (Sustainable Energy Authority of Ireland) in its Heat Pumps - Operation and maintenance Guide, status records must be kept throughout the operating life of the system, so the evidence of a proper maintenance can be shown. It is highlighted that proper records should include drawings and schematics to reflect any amendments made to the system, maintenance records as well as meter records (to support performance monitoring), that can be automated thanks to remote diagnostics and compliance records (to demonstrate that the operator has followed the regulatory requirements).

#### TYPE OF ACTION

Status reporting delivers mainly to research as it provides data regarding the maintenance history, guides on how the system has been updated, as well as the performance data.

#### RESULTS

Real time information about the status of a HVAC system that is easy to understand enables to correctly assess and carry out maintenance activities.

### LINK TO POLICY FILES

There is no legislation covering specifically that the reporting of a HVAC system should be easy to understand. However, everything related to real time information that an HVAC system can deliver is covered by Ecodesign Lot 1 and 2.



## **4.6.1 HEATING AND COOLING AS A SERVICE**

#### **OBJECTIVE**

With H&CS the customer pays only for the heat supplied or warmth outcome, rather than the fuel input. In order to do so, the energy supplier uses customer and property characteristics to come up with a custom-made heating solution. The energy supplier is the one in charge for owning, maintaining and operating the HP.

#### **KEY ACTIONS**

Heat as a service models should be considered a tool for the decarbonisation of heat:

•They can enable customers to invest in more expensive solutions as the higher upfront costs of low carbon solutions are spread over a contract period of several years;

•Providers can secure more competitive product and energy prices by sourcing heating solutions in bulk rather than individually;

•The customer journey becomes simpler as the

#### **CURRENT STATUS**

The traditional H&C market is opening the door to newer, customer-centric approaches, nevertheless as indicated by <u>DELTA EE</u> in its <u>the 2020s is the decade</u> <u>to decarbonise heat</u> issue, as of today, only a small fraction of heating systems are sold as a service-based heat offering.

In the last 3-5 years there has been a fast transition from mainly trials and demonstration projects, to commercial offerings. In the last 1-2 years especially, low carbon solutions have been increasingly added to the available offerings, e.g. the <u>SunPeople project</u>.

process of switching to a low carbon heating system is simplified in part by providing a "one-stopshop" service;

•There is an optimisation of the timing and quantity of energy flows within the home and/or between the energy system;

• The HP is easily replaced (upgraded to a newer HP).

#### **TYPE OF ACTION**

Heat as a service should be considered an innovation for the sector as it is a tool that can play an important role in the decarbonisation of heat. Nevertheless, examples of its application, still need to be carried out for the full development of the model's potential. These actions should be accompanied by a concerted communication campaign to showcase the new approach.

#### LINK TO POLICY FILES

ESCO's and energy performance contracts are covered by the Energy Efficiency Directive and their importance is stressed in the Renovation Wave Communication.

#### RESULTS

Heat as a service models can contribute to the decarbonisation of heat by creating tailor-made systems that not only allow customers to easily invest in low carbon solutions but also, allow providers to secure more competitive products and prices.

## **4.6.2 DISPOSAL AND RECYCLING STRATEGY**

#### **OBJECTIVE**

Repairing/upgrading an existing heat pump unit might prove to be a less expensive alternative if the repairs/ upgrades are minor, but not cost-effective after a certain timeframe. It is crucial to take into account that older units use significantly more energy than newer counterparts, as well as that their energy consumption may continue to climb as they age. Therefore, it is important to design a disposal and recycling strategy that provides advice on when, why and how to replace/upgrade a heat pump unit.

#### **KEY ACTIONS**

- Development of concrete actions for the recycling and disposal of the different parts of the HVAC systems;
- Development of clear guidelines for understanding how, why and when it is necessary to replace/ upgrade a heat pump unit;
- Highlight that HPs are part of the EPR and promote as an integral part of the circular economy.

#### **TYPE OF ACTION**

Innovation in the development of tools and strategies for the proper recycling and disposal of Heat Pump units and other HVAC systems beyond refrigerants.

#### **CURRENT STATUS**

Currently, the concept of Extended Producer Responsibility (EPR) is applied to HPs. With HPs, being listed under the category of "temperature exchange equipment" under the Waste from Electrical and Electronic Equipment <u>WEEE-Directive (2012/19/EU)</u>. With a specific annex (VII) on the disposal/recycling and treatment of materials and components. In addition, CEN-CENELEC developed WEEE treatment standards that also apply.<sup>16</sup> With either the company that installs the new system taking care of the recycling and disposal of the unit, or sometimes, this falling under the responsibility of the previous user.

Companies like Daikin, nevertheless, have strategies to stimulate refrigerants circular economy (<u>LOOP by</u> <u>Daikin</u>). The <u>New Circular Economy Action Plan</u> by the European Commission, published in March 2020, announced the presentation of a "Circular Electronics Initiative" that will promote longer product lifetime as well as regulatory measures for electronics so that devices are designed with energy efficiency, upgradability, maintenance and recycling in mind.

#### RESULTS

 Informed costumers that will know when it is necessary to replace/upgrade their heat pump unit as well as how and what can be recycled;

- A cost effective-solution for HVAC users;
- Stimulation of circular economy thanks to the recycling of heat pump components.

#### LINK TO POLICY FILES

Currently, the concept of Extended Producer Responsibility (EPR) is applied to HPs. With HPs, being listed under the category of "temperature exchange equipment" under the Waste from Electrical and Electronic Equipment <u>WEEE-Directive (2012/19/EU)</u>.

The <u>New Circular Economy Action Plan</u> by the European Commission, published in March 2020, announced the presentation of a "Circular Electronics Initiative" that will promote longer product lifetime as well as regulatory measures for electronics so that devices are designed with energy efficiency, upgradability, maintenance and recycling in mind.

<sup>&</sup>lt;sup>16</sup> CEN-CENELEC Final Report Ref. No. FprEN 50625-1:2013 E, Septemebr 2013: Collection, logistics & Treatment requirements for WEEE -Part 1: General treatment requirements



# **5. IMPLEMENTATION PLAN**

esources such as: time, research, innovation, financial and economic investment, as well as pilot sites and various tests via private, public (or a combination) of capital, have already been dedicated to the diverse life-cycle steps indicated in this document. With exact figures or quantities of said resources being very difficult to accurately gauge, as most (if not all) are being utilised in private programmes and by private entities, and even deliverables from EU funded projects sometimes being classified as confidential. This approach is used as the innovations associated with such research comprise of new product lines, approaches or logistics, that require not only a significant resource effort from the entity undertaking them, but are sometimes the differentiator between different brands, their technology, processes and ultimately, their success.

The general results of each action or set of actions have been added to each objective, and where suitable one or more examples were provided, along with the associated steps (if available) required. Though such complementary areas such as: the budget and financing for the research priorities, requested funding to implement the action plan, proposed timeline (for the implementation of research priorities/topics) are difficult to calculate or even estimate, especially since each research and innovation priority has its own scope and set of dependent measures (as well as potentially requiring some type of single or multitude of technological and/or process innovation/s), and a more or less direct relationship with both the policy and funding spheres (bespoke, regional, National, EU level and International).

However, for a general estimation of the different type of resources required, the proposed research would be to compare another technological shift currently underway, this being the undergoing and accelerating transition from internal combustion engines (ICE) to electric vehicles (EVs) with the investment, policy, research, innovations and timelines needed in that field. These fields are very much intertwined, as there are many similarities and indeed parallels and dependencies between them. To name a few: policy shifts, funding into research and adoption (including grants and tax breaks), use and upgrading of the existing electrical grid (including share of renewable energy present in the electricity mix), new processes and significant infrastructure investments (new and bigger factories and manufacturing capabilities), new ways of manufacturing and design, new ways of product distribution (online direct orders and configuration), connectivity, AI and user interfaces, thermal and electrical storage (used in many systems that employ HPs), replacement of fossil fuels with electricity, new consumer messages and communication strategies. Indeed, new EVs also employ a HP in their design as to provide H&C far more efficiently than the alternatives. Moreover, the mass deployment of HPs to replace current fossil fuel solutions and fulfil policy and environmental targets, brings with it many of the same logistical considerations and a complete analysis of the complete life cycle of a HP.

Just in 2020 in Europe, 60 billion euro were dedicated to producing EVs and the batteries associated with them (an increase of 19 times from 2018),<sup>17</sup> with a large percentage of current automobile manufacturers around the world starting to move into or committing to all EVs in the next decades, very much like to policy and manufacturing moves in the Renewable Heating and Cooling sector. As such, as in the case for EVs, an order of magnitude more resources, year over year, will need to be dedicated to strategic research and innovation with the upside that, such investments will have direct contributions to a lot of other sectors (e.g., job creation, circularity) and that mass deployment will also mean mass manufacturing and significant economies of scale.

Record €60bn investment in electric cars and batteries in Europe secured last year, Transport and Environment, by Eoin Bannon, 25 May
 https://www.transportenvironment.org/press/record-%E2%82%AC60bn-investment-electric-cars-and-batteries-europe-secured-last-year







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