A digital revolution for the built environment?

Flexibility, comfort, and new business models for heat pumps.

White Paper

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Foreword

The positive impact of digital solutions is being felt in every sector at an ever-increasing pace because of technological improvements, interconnection (data gathering and analysis, design, etc.) and a change in the legislative landscape. This paper provides an overview of the emergence of digitalisation in the heating and cooling sector, in particular in building applications. It elaborates on the consequences of this trend for the **heat pump industry** including improved system reliability, consumer comfort and business opportunities.

In conjunction, the use of heat pump-based systems could increase efficiency whilst closely catering to the comfort requirements of its users. Overall reduction in demand, as well as the ability to shift demand from times of shortage of electricity to times of abundance (Demand side flexibility) allows for the cost optimisation and brings economic benefits, as well as optimal use of fluctuating energy generation (i.e., wind, solar) and storage (thermal, electrical). It is expected that the cost reduction potential of heat pump operations under market conditions that reward flexibility will lead to new business models and may attract new actors to the heating and cooling sector.

This combination of sector coupling, regulation and technological development is the foundation for the growth of new markets including entwined social and economic aspects. This document presents the state of play in three key areas of digitalisation, the related policy framework, and a perspective on the opportunities of digitalisation for the heat pump sector. It will also look at the different actors that can and likely will play a role in pushing the heating and cooling sector towards the digital age.

The European Heat pump Association (EHPA) is excited about the opportunities presented by digitalisation, as they will enable a flexible integration of heat pumps in an increasingly renewable based electric grid. A higher share of renewables will eventually lead to lower fuel cost but will require more demand side flexibility. Heat pumps can provide this flexibility thus stabilising the grid and benefiting from the value given to flexibility by further reducing the operating cost of heating and cooling. As a consequence: Flexibility has the dual benefit of increasing comfort for the end-user (by providing a tailored service at a potentially lower price, with an active engagement of the end user) and promoting the integration of renewables in the energy system (by allowing residential buildings to be more independent from the grid). At the same time, digitalisation creates new challenges as interfaces need to be standardised and end-user energy data needs to be protected in line with privacy and cybersecurity concerns.

Next to the status quo of technology and the presentation of application opportunities, this paper will shed light on the relevant EU policy framework, giving recommendations as to the efforts needed for implementation and pointing to actions deemed necessary by policy makers.

List of Acronyms:

BACS	Building Automation and Control Systems
BEMS	Building Energy Management System
BIM	Building Information Management
DR	Demand Response
DSF	Demand Side Flexibility
EC	European Comission
EHPA	European Heat Pump Association
EMS	Energy Management System
ENISA	the European Union Agency for Nextwork and Informative Security
EPBD	Energy Performance of Buildings Directive
EU	European
HAN	Home Area Networks
HP	Heat Pump
HVAC	Heating, Ventilation, Air-Conditioning
ICT	Information and Comunications Technology
IEA	International Energy Agency
IoT	Internet of Things
PV	Solar PhotoVoltaic Panel
SCI-BEMS	Self Correcting Intelligent - Building Energy Management System
SRI	Smart Readiness Indicator
VOC	Volatile Organic Compounds

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1. DIGITALISATION

Definitions and Scope

1.1 What is digitalisation?

The term digitalisation refers to shifting analogue processes or devices into a digital form.

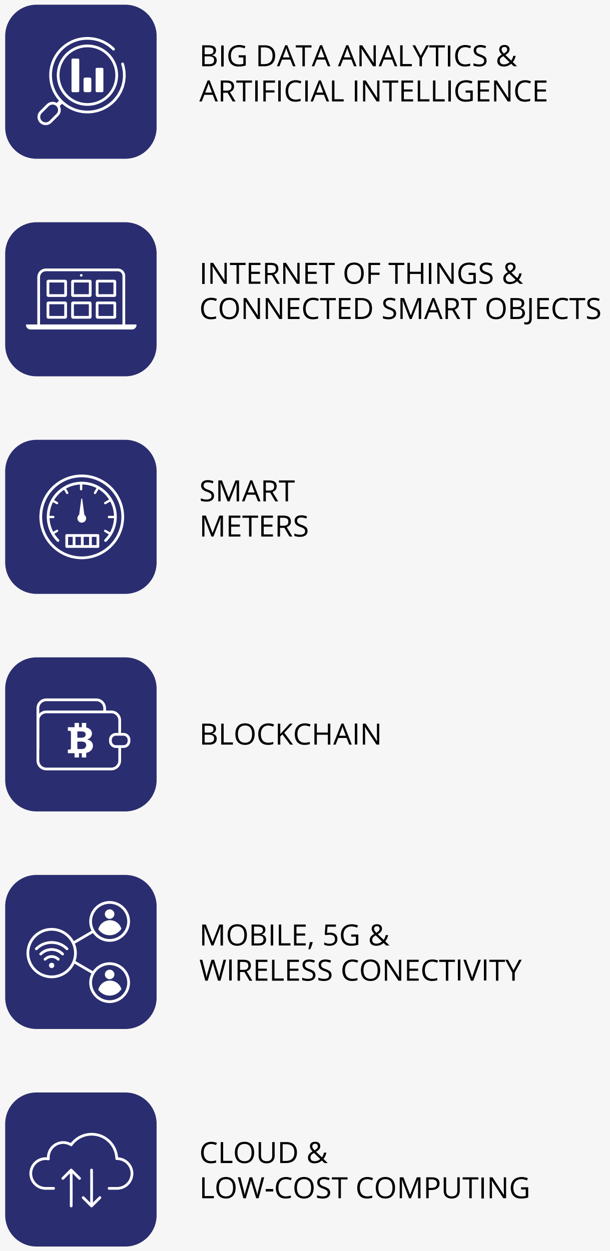

Figure 1. What is Digitalisation?[2]

"Digitalisation is the innovative use of information and communications technologies, in particular the large-scale rollout of smart devices and sensors, and the use of big data collection and analysis."[1]

The European Commission's Strategy for Energy System Integration, "Digitalisation supports energy system integration", points out that digitalisation enables:

- Connection to different markets: matching supply and demand at a more disaggregated level and closer to real time, including that of different energy carriers: electricity and heating/cooling,
- Enhanced forecasting,
- Remote monitoring and management of distributed generation,
- Improved asset optimisation,
- The unleashed flexibility potential of customers, contributing to an efficient integration of renewables,
- Economic growth and technological leadership.[3]

From these findings it can be concluded that digitalisation not only brings many tangible benefits to energy system integration, (and therefore to the heat pump industry) but is also essential to making the benefits a reality. Below are two examples which illustrate how this might look in practice for both the building sector and the heating and cooling sector.

[1]Lyons, L. (2019). Digitalisation: Opportunities for heating and cooling. Publications Office of the European Union: Luxembourg.
SolarPower
[2]Europe, (2020).Digitalisation & Solar In Emerging Markets - Task Force Report
[3]European Commission (2020), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Powering a climate-neutral economy: An EU Strategy for Energy System Integration, p. 18

1.2 Digitalisation in the building sector

"Buildings consume energy, but they can also produce and store energy in ways that make the entire energy system more flexible and efficient".[4]

We are living in the Information Age. With current projections estimating a worldwide population of 7.8 billion, it can be supposed that approximately 4.93 billion people have access to and use the internet frequently.

This means that the 63,2% of the population uses the internet, with an increase of the 1,266% from year 2000 to 2020.[5] However, now an even larger number of devices are connected to the Internet and can source information from it as well as providing data themselves.

There are currently millions of machine-to-machine devices being used, with estimates that this will reach 5 billion by 2022. [6]

It is this machine-to-machine communication that will power the optimisation of heating and cooling and as part of the electricity sector.

A smart building involves the installation and use of advanced and integrated building technology systems. These systems, often referred to as building information management (BIM) systems include various sensors, controllers, actors, controllable pumps, and valves as well as cameras and microphones. On site or connected to remote servers and services, they are used to provide connectivity, safety, and comfort solutions to the building. [7]

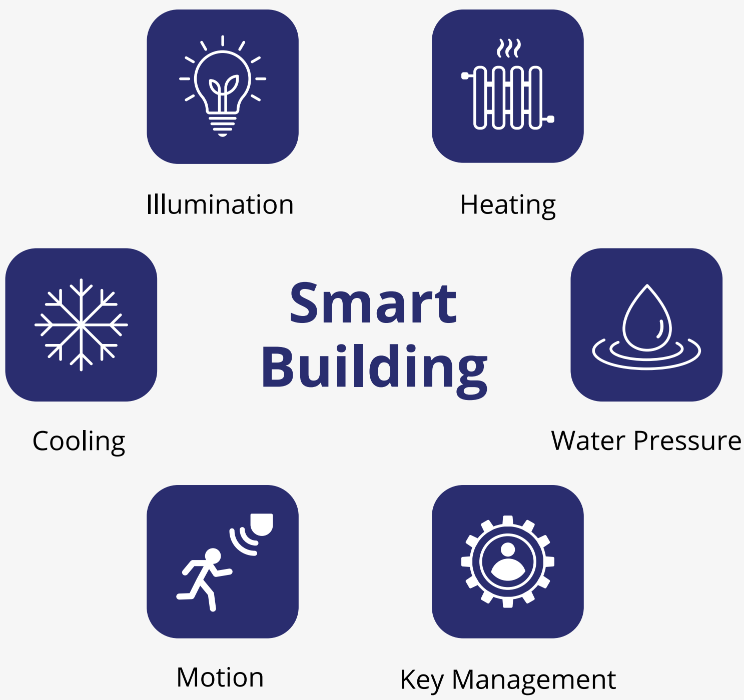

Figure 2. Smart building connections

[4]Smart Energy Europe, (2019), A vision for smart and active buildings,
[5]Last access on the 05.02.2021: https://www.broadbandsearch.net/blog/internet-statistics
[6]ISSQUARED, (2020), Machine to machine communication and connected reality, https://www.issquaredinc.com/machine-to-machine (last access 19/02/2020).
[7]James Sinopoli,(2010), Smart Building Systems for Architects, Owners and Builders, link here

Focusing on heating and cooling, smart buildings provide actionable information about a building to allow the occupant to enjoy a healthy and comfortable indoor environment. Within a smart building all components are connected, from air conditioning to security and lighting (see Figure 2). End users are driven to choose smart building solutions to increase comfort, reduce energy consumption, improve building efficiency, increase economic benefit, and allow predictive maintenance.

In the distant past, a heater had an on/off switch, and then logic boards and external temperature sensors were added. Today, sophisticated controls in heating/cooling devices (microcontrollers to control boilers, HVAC systems, cooling devices and heat pumps.) or the building provide all the services described above to provide indoor comfort and (electricity) system support. With more powerful controllers, more affordable and versatile sensors, and increased user demand, comes the option to control multiple zones in a building, store and evaluate data and connect the heating /cooling device to other applications and even to the electric grid.

The more components that are integrated and connected, the more complex yet the more powerful the system becomes. Thus, standards that allow components of different origin to communicate with each other and a user-friendly interface are important factors influencing the success of digitalisation in buildings.

Components making products, systems, buildings, quarters and cities digital are:

- Microprocessors,
- Indoor and outdoor sensors for temperature, pressure, CO2, Volatile organic compounds (VOC) as well as audio and video data; sensors can be wired or wireless,
- actors, controllable motors, valves and pumps, and an interface to other devices such as a building energy management system (BEMS), the internet or even the electric grid,
- Access to services providing weather data, price information and other service offerings. These interfaces are often bi-directional to make individual buildings data available to the installer, a service provider, the building owner or a utility.

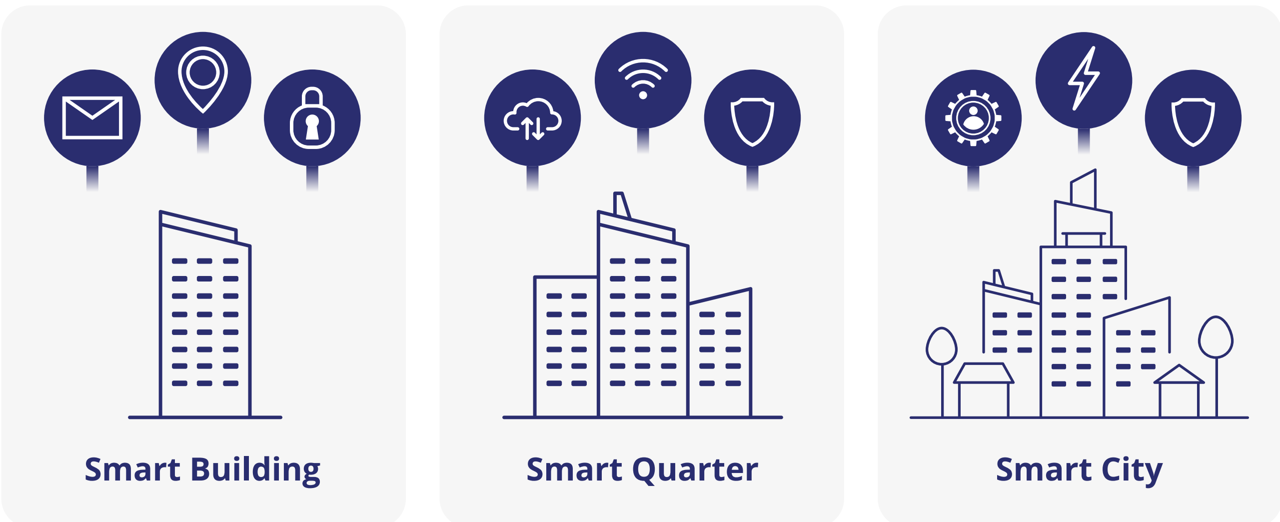

Figure 3. Smart Building, Smart Quarter & Smart City Integration

What does digitalisation mean for the HP industry and where do we stand?

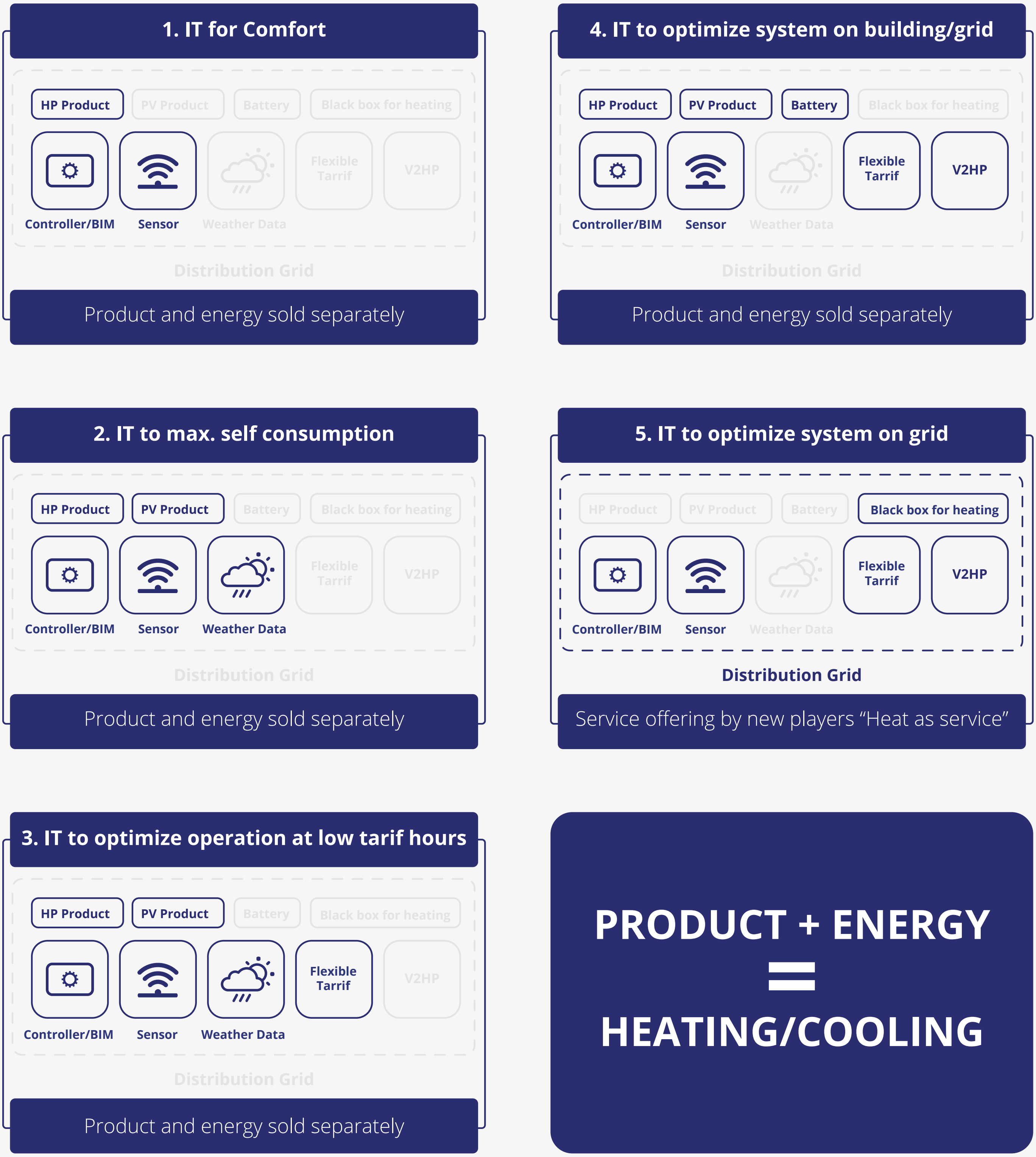

Figure 4. What does digitalisation mean for the heat pump industry and where we stand

Considering a fully electrified building of the future, the following components will be necessary to provide heating and cooling comfort, hot water, electricity generation and storage:

1. The refrigerant cycle-based system for heating, cooling and hot water (typically referred to as 'heat pumps' and air conditioning)
2. The ventilation system (which may include the functions mentioned under #1)
3. A thermal battery (also referred to as storage tank using either water or phase change material for energy storage and release)
4. An electric battery
5. An electric vehicle
6. A photovoltaic system with an inverter
7. A dedicated controller connecting all components
8. A connection to the electric grid and the internet via the controller interface.

The devices numbered #1, #2, #4, #6 and #7 can serve as master controllers for the whole system. While it is not clear which components may become the dominant controller in and of a building, heat pumps are good candidates due to their onboard sophisticated controllers, sensors and internet connection.

Similarly, there is no agreement (yet) on a standard interface and communication protocol between these components.

Figure 4 illustrates different **levels of digitalisation from the heat pump perspective.**

In Box 1: Every heat pump has a microcontroller and one or more sensors to provide indoor comfort to the building in which it is installed. It may be connected to a building level controller.

In Box 2: With more electricity being used in buildings, a typical mix of solutions is a PV generator on the roof and a heat pump in the basement. They can operate independently, but if the maximisation of use of self-generated electricity is aimed for, both should be connected.

The heat pump follows the supply curve of the PV generator as much as possible. It reacts to the current and forecast weather. Electricity can be stored as heat in a hot water tank or the thermal mass of a building.

In Box 3: An additional component next to a heat pump and a PV generator is a flexible (time of use) tariff. In this set-up, the heat pump reacts to available / expected provision of electricity from the on-site array as well as to price signals from the grid and operates under the condition of providing end-user comfort.

In Box 4: An even more sophisticated system would include an electric battery and an electric vehicle, allowing the use of electric storage both in the stationary battery and in the vehicle.

A 10kWp battery provides sufficient energy for a few hours of heating/hot water.

In Box 5: Finally, the control of the building could also be governed via the grid, integrating, and optimizing local supply and demand and setting it into an overarching context, allowing systems optimisation while maintaining user comfort.

A solution to this issue is to provide heating and cooling systems, operating with a higher level of microcontroller and sensor integration. This can provide a several benefits, such as:

- Improved efficiency:
  - Increased use of renewable energies;
  - Increased utilisation factor of wind turbines and PV electricity generators;
  - Providing grid stabilisation by using load shifting options. If thermal energy can be stored in thermal batteries (PCM, water) or the thermal mass of the building (walls, floor heating, radiators) demand can be shifted from times of electricity supply shortage to times of oversupply;
- Reduced operational cost and energy consumption:
  - Using a flexible electricity price in combination with the named flexibility leads to (potentially) significant savings;
- Much lower, potentially even negative prices for electricity during times of oversupply;
- Increased end user and social awareness, and increased interoperability with other elements, such as grid flexibility and smart appliances;
- Due to the constant data flow and monitoring is easier to identify any malfunctions and promptly intervene with maintenance.

However, this interconnection needs to take in account how data are treated and protected, to avoid any cybersecurity thread (more in paragraph 2.5).

Utilities and service providers see smart buildings as active nodes in an energy system providing flexibility and allowing for higher utilisation rates of the different assets deployed.

For them, smart buildings are the tool to system optimisation. They are an essential part of an integrated energy system. Despite the theoretical benefits, few real solutions exist in the market.

From a decarbonisation perspective, *"Heating and cooling constitutes around half of the EU's final energy consumption and is the biggest energy end-use sector, ahead of transport and electricity.This shows that the heating and cooling sector has a crucial role to play in the EU's transition towards an energy efficient and decarbonised energy system and in achieving long term energy security".* [8]

Therefore, a prompt and strong action in the heating and cooling sector is needed.

[8]European Commission, "Heating and cooling", last access: 19.02.2021, https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en

1.3 Policy Framework

The importance of sensor equipped, connected devices is also recognised in policy. There is no agreement yet on whether standards for these devices need to be set by regulation or will be developed through the market.

Legislation is currently discussed or prepared on:

- Communication standards of smart products with the electric grid (network codes);
- Providing information on smart products via the energy label;
- Ensuring and protecting end-user data and privacy.

ECODESIGN LOT 33 on Smart appliances:

A new renewable energy-based and smart energy system requires smart appliances to be able to interact with each other and with the grid in order to exploit their full balancing potential. In the framework of Ecodesign Lot 33, the European Commission commissioned a study in 2014 to analyse all technical, economic, environmental, market and social aspects relevant for a broad market introduction of smart appliances. [9]

The European Heat Pump Association (EHPA) being amongst the consulted stakeholders. The latest draft report recommended the inclusion of a reference under the form of an icon in the Energy Label, combined with a label information requirement under the Ecodesign regulations as the best policy instrument.

Indeed, such an option has the advantage of not limiting consumers' choice, but to provide uniform information to enable better comparison of products, as well as to ensure compatibility of energy-smart appliances. [10]

Although the study was expected to be finalised at the end of 2017, the deadline was postponed. As of today, we have no certainty as to the future of this file.

The European Commission is reconsidering its approach on Lot 33 as there is a lack of evidence justifying the regulation, and there is a high possibility that Lot 33 will be moved out of the Ecodesign framework.
On a more positive note, a voluntary code of conduct for the industry is being developed and should be presented to the stakeholders mid-2021.

[9] European Commission, (2015), Preparatory Study on Smart Appliance,
[10] European Commission, (2017), Preparatory Study on Smart Appliance, Task 7 Policy and Scenario analysis,

ECODESIGN LOT 38 Building Automation and Control Systems:

While Lot 33 looks at the smartness of the product, Lot 38 focuses on its functionality. Building Automation and Control Systems (BACS) are electronic appliances that manage and control the operation of most technical building services.[11] BACS can realise significant energy saving due to their interaction with other products.

According to the preparatory study of the European Commission, the main energy savings are driven by the coordination of several controlled products with BACS.[12]

In the framework of Ecodesign Lot 38, the European Commission commissioned a study in October 2017 to complement the on-going studies addressing the development of a smart readiness indicator for buildings and smart appliances under the Ecodesign Directive.[13]

Among the consulted stakeholders, EHPA participated in the first and second stakeholder meetings. The study is still ongoing and is expected to be finalized by the end of 2021.

The draft final report will soon be published by the Commission and Consultants, which should give stakeholders a better understanding of the impact and/or opportunities of Lot 38 for the heat pump industry.

Smart Readiness Indicator Level (SRI):

Under the Energy Performance of Buildings Directive (EPBD)[14] the European Commission has developed a Smart Readiness Indicator (SRI) for buildings as an instrument for rating the smart readiness of the building. [15]

The SRI aims to rate the capability of a building to optimise energy efficiency, adapt to the needs of the occupant(s), and adapt to signals from the grid.

Once the Smart Readiness Indicator is set, there will be a common meter used in rating buildings capacity to adapt to energy optimisation and to adapt their operation in reaction to signals from the grid, ensuring energy flexibility.

This will show the savings that are possible to obtain form smart buildings.

The delegated and implementing acts have just been adopted by the European Commission.

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[11]European Commission, (2017), Preparatory Study on Building Automation and Control Systems,
[12]European Commission, (2017), Preparatory Study on Building Automation and Control Systems, Task report on scoping,
[13]European Commission, (2017), Preparatory Study on Building Automation and Control Systems,
[14]Energy Performance of Buildings Directive (EPBD):
https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF
[15]https://smartreadinessindicator.eu
[16]BUILDUP, (2020), Final report on the technical support to the development of a smart readiness indicator for buildings, last access on the 04.03.2021,
https://www.buildup.eu/en/practices/publications/final-report-technical-support-development-smart-readiness-indicator

Following the official publication of the documents, the Member States will start the testing and implementation of the SRI on a voluntary basis.[16]

In September 2020, the European Commission has also launched a tender to secure technical assistance in the phases of the testing and implementation of the SRI. Member states will be able to work closely with the selected consultants in respect to national implementation. The consultant will provide direct support to the Members States and stakeholders, prepare guidance and supporting documents, and create an SRI platform which consist of a multi-stakeholder forum.

The name of the selected consultants has not been shared with the public for the moment.[17]

Energy Performance of Buildings Directive (EPBD):[18]

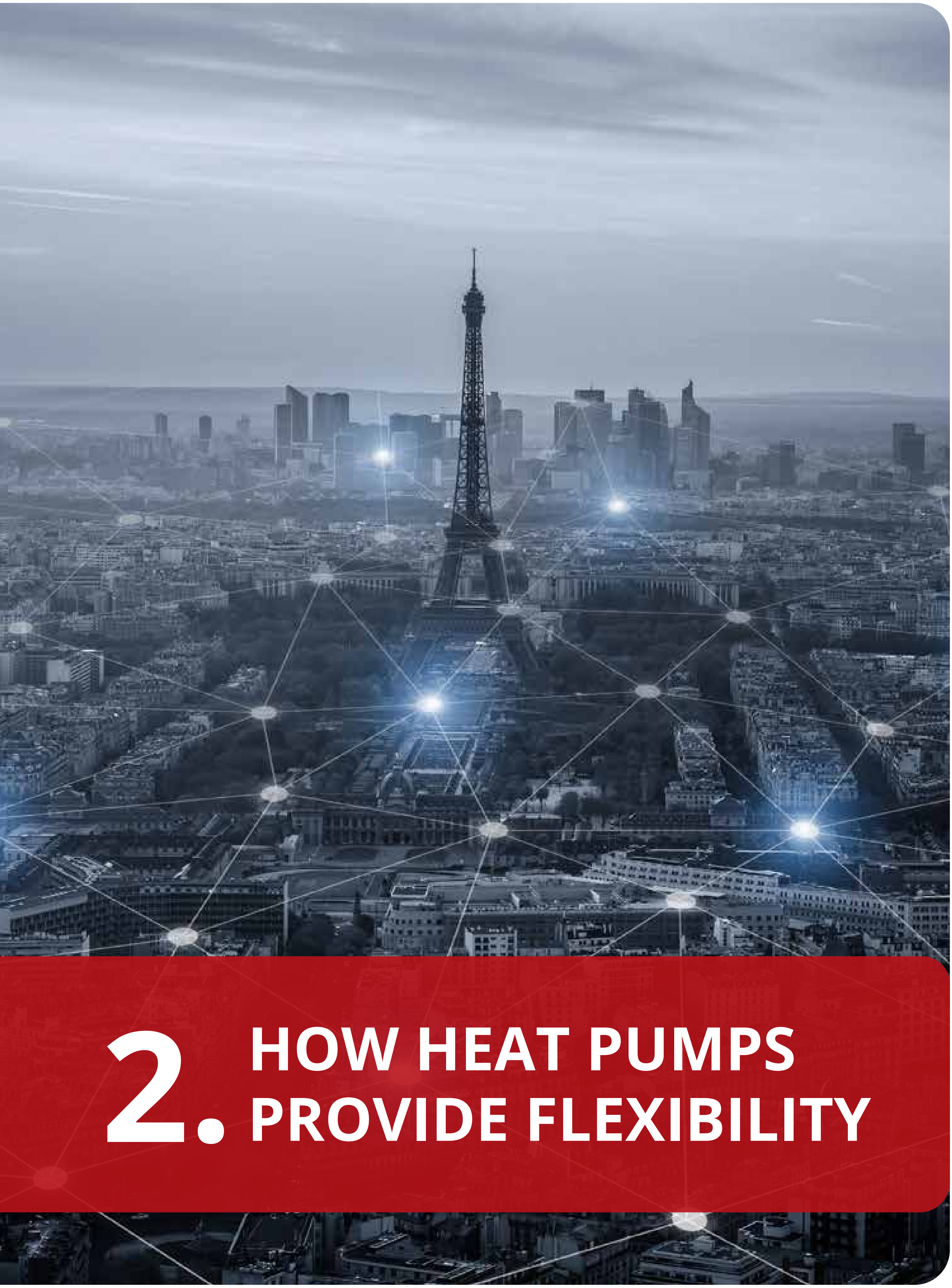
The Energy Performance of Buildings Directive 2010/31/EU (EPBD) and the Energy Efficiency Directive 2012/27/EU were both amended by the Clean energy for all Europeans package in 2018 and 2019.

The amended "Energy Performance of Buildings Directive" (2018/844/EU) introduces new elements and sends a strong political signal on the EU's commitment to modernise the buildings sector in light of technological improvements and increase building renovations. [19]

In the directive, particular importance is placed on the development of nearly zero-energy buildings (NZEB), support for electro mobility, an optional European scheme for rating the 'smart readiness' of buildings and smart technologies are promoted, including through requirements on the installation of building automation and control systems, and on devices that regulate temperature at room level. BPIE fears that the Commissions targets do not go far enough in their efforts to achieve climate goals, stating that Europe needs to reach at least '3% deep renovation rate, combined with a push for renewable heating and cooling of our buildings'[20] if 2030 targets are to be achieved.

As 'buildings have the potential to be at the forefront of providing flexibility to the energy system' it is important that this Directive meets its objectives.[21]

[17]Technical Assistance for Testing and Implementation of the Smart Readiness Indicator under the Energy Performance of Buildings Directive, last access on the 04.03.2021, https://etendering.ted.europa.eu/cft/cft-display.html?cftId=6874#caDetails
[18]Energy Performance of Buildings Directive (EPBD):
https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF
[19]European Commission, "Energy performance of buildings directive", last access: 16.02.2021,
https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en
[20]EURACTIVE,
https://www.euractiv.com/section/energy/news/complete-overhaul-of-buildings-needed-to-meet-eus-2030-climate-goal/
[21]BPIE, (2019), "FUTURE-PROOF BUILDINGS FOR ALL EUROPEANS"



2. HOW HEAT PUMPS PROVIDE FLEXIBILITY

The electricity system was originally built around central, large power stations that delivered electricity to millions of end users.
In this system, generation followed demand.

The uptake of variable renewable energy generation from wind and photovoltaic has changed the landscape. Their capacities are much smaller; however, they are plenty.

Availability of electricity depends on available sunshine and wind, making storage, demand side flexibility and peak load generators necessary to comply with demand. At least currently, storage capacity for electricity is still limited – thus a largely renewables-based system will have to be operated following supply. The more flexible demand solutions are in such a system, the better.[22]

Digitalisation allows for the interconnection of such solutions and enables the shifting of load in the grid.

The information exchange between supply and demand enables a rapid and adequate response and thus helps maximise the use of available energy and supports a stable energy system. Buildings provide this kind of demand-side flexibility (also referred to as "demand response").

WHAT IS DEMAND-SIDE FLEXIBILITY?

Demand side flexibility (DSF) can be defined as the ability of a customer (or Prosumer – someone who produces as well as consumes) to deviate from their normal electricity consumption (production) profile, in response to price signals or market incentives. Demand side flexibility consists of:

- Load
- Demand side generation
- Demand side storage.[23]

Demand side flexibility can be either implicit or explicit.

Implicit demand-side flexibility refers to consumers' behaviour regarding the price signals, i.e., the ability to choose hourly market pricing, making it "price-based" demand side flexibility. This agreement is usually provided by traditional suppliers and is called a "time-of-use" or "dynamic price contract".[24]

While the **explicit demand-side flexibility**, is a form of "incentive-driven" flexibility, and its normally managed by an aggregator who stipulates an agreement with the consumer, to avoid having electricity demand in the peak loads, in exchange of monetary incentives. This agreement is known also as "aggregators contract".[25]

Consumers can adopt demand side flexibility in their smart house or building and get maximum economic advantage while using their electrical devices. The active role of

[22]Several studies exist that have shown that a 100% renewables based energy system is feasible and affordable, for example:
a) https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf
b) Energy watch group: https://energywatchgroup.org/globales-energiesystem-mit-100-erneuerbaren-energien)
[23]European Smart Grids Task Force, Expert group 3, (2019) Final report.
[24]BEUC,"Fit for the consumer?"
[25]SMART ENERGY EUROPE (2019), A vision for smart and active buildings

consumers, and the use of smart appliances (I.e., smart heat pumps), can unlock the full potential for demand side flexibility and grid flexibility.[26]

Consider a residential building, with an Energy Management System (EMS) combined with decentralized energy devices like heat pumps, battery storage, and solar PV- self-consumption optimisation can be ensured.

This can be optimised even more if the EMS in the building connects to smart meters, which can communicate external data, such as electricity prices and weather data.

Weather data can be relevant for the optimisation of the heating and cooling systems. If the smart meter is connected to the public open meteorological services, its data can be accessed and analysed by the EMS, and then translated into actions, like the activation of the heating or cooling system according to the comfort protocol set by the user. The EMS collects non-validated near real-time consumption data and the communication with smart meter occurs via Home Area Networks (HAN).[27]

On the other hand, with regards to electricity prices, the EMS **can support network flexibility,** and the energy devices can be harnessed to use energy when it is most cost-effective, while reducing the consumption at moments when the electricity system is under pressure. This coincides with **Demand Side Flexibility** which is the ability of the consumer to adapt their electricity consumption in response to the market signals.

When the consumer is inclined to adopt behaviours, which lead to short-term reductions in energy demand as a response to market-price signals, demand could also be met **by using (available) on-site generation and storage assets.** [28]

This makes buildings more "energy independent" with multiple benefits both for the single user and society, since demand side flexibility can help to relieve the electricity system, preventing black-outs, and reducing the total generation capacity needed in peak hours.

There are different ways to activate demand side flexibility, but what appears to be fundamental is that:

- The building should be furnished with smart devices.
- Active consumers who adopt measures to be more energy independent and are comfortable in adapting their energy behaviour.
- Informed consumers – we must ensure equal possibilities and provide clear information to the consumers on the different electricity prices (at which time the prices are higher and lower), without any discriminations, and with common approaches in Europe.

[26] "Grid Flexibility" refers to the capability of a power system to maintain balance between generation and load during uncertainty, resulting in increased grid efficiency, resiliency and the integration of variable renewables into the grid". Definition taken by Louis Basington, "Smart Grid Flexibility Markets – Entering an Era of Localization", (2020) Ceantech Group. access on the 28.05.20 https://www.cleantech.com/smart-grid-flexibility-markets-entering-an-era-of-localization/
[27] DG Energy, PwC, Tractebel, (2020), Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market.
[28] SMART ENERGY EUROPE (2019), A vision for smart and active buildings

2.1 Policy Framework

When transposing the different Directives of the Clean Energy package into national law, in particular **the Electricity market design directive** and the **revised Energy Performance of Buildings Directive,** national policymakers should foster and eliminate the existing barriers to **unlock the demand-side flexibility of buildings.** In this way, homeowners and energy managers would be incentivised to invest in flexible assets and rewarded to participate in flexibility programmes. [29]

Electricity market design directive:[30]

The share of electricity produced by renewable energy sources is expected to grow from 25% to more than 50% by 2030. [31]

To better meet sufficient quantities of electricity produced by the sun and/or wind, there is a need to invest in energy storage to allow the consumer to be proactive and independent (due to the risk of limited sunny days), as well as contributing to keep the electricity system stable from the renewable energy production.

To allow this shift, policy makers need to invest in consumers, and a first step in this direction was provided by the "Clean energy for all Europeans package" (adopted in 2019), that will help in adapting EU market rules to new market realities.

As another important milestone, the EU is putting the consumer at the centre of the energy transition. The Electricity Directive aims at enabling the consumer participation and protect their rights, by allowing electricity to move freely between countries, and so consumers can benefit from cross-border trade and competition.

These EU initiatives aim at contributing to re-designing the electricity market and increasing the share of renewables to achieve carbon neutrality by 2050 and the EU Green Deal goals.

From the data reported by SMARTen[32] very few Member States are concretely working to eliminate existing barriers, therefore an extra effort needs to be implemented on a national level to achieve the EU targets. For instance, free access to data (with the user's consent) would be a 'major enabler of innovative services' however, the only Member States to have set national laws requiring this so far are France, Finland, Germany and Slovenia. [33] More must be done on a legislative basis to support the rapid growth of digitalisation.

Energy Performance of Buildings Directive (EPBD), already mentioned in chapter 1.1.

[29]SMART ENERGY EUROPE (2019), A vision for smart and active buildings
[30]The Directive on common rules for the internal market for electricity(EU) 2019/944, which replaces Electricity Directive (2009/72/EC), and the new Regulation on the internal market for electricity (EU) 2019/943, which replaces the Electricity Regulation (EC/714/2009) on January 1 2020.
[31]European Commission," Electricity Market Design", https://bit.ly/2N1tqAx, last access on the 16.02.2021
[32]SMART ENERGY EUROPE, (2020), The implementation of the electricity market design to drive demand-side flexibility 2020.
[33]SMART ENERGY EUROPE, (2020), The implementation of the electricity market design to drive demand-side flexibility 2020.

2.2 Opportunities for the Heat Pump market

Heat pump-based systems can store energy in hot water tanks and the thermal core of the building.

They can be utilised as a “thermal battery” using surplus electricity to heat or cool the storage, while switching of the device in times of supply shortage User comfort is maintained through distributing the stored energy from the storage. [34]

Even a basic heat pump system (see box Nr.1 in figure 4), can provide heating and cooling for several hours without the need of significant grid-based electricity. More sophisticated systems with electric batteries and local PV generation can provide such services even for a day or two. [35]

Based on today’s heat pump stock (in 2020 we counted 14.6 million units which provided 159 TWh renewable energy),[36] the flexibility potential is assessed at between 1TWh and 3TWh per year. Transforming this potential to reality requires a value to be given to flexibility via time of use tariffs. Their introduction is expected from 2021 onwards, but the status of implementation is still insufficient.

Smart technologies like smart heat pumps can unlock the potential for demand side flexibility and grid flexibility while connecting with other smart appliances. According to the European Commission’s study group, energy-smart appliances are defined as those that can automatically respond to external stimuli (I.e., price information, direct control signals, and/or local measurements) and change their electricity consumption pattern. Heating, ventilation, and air conditioning systems (HVAC appliances) were identified as the area having the highest potential for demand response.

Heat pumps have a lot of potential in terms of demand-side flexibility, and they can play a key role in the flexibility of the grid. Being the most digitally advanced heating system that responds automatically to external stimuli, it is important that the heat pump industry remains at the forefront of these changes and continues to innovate by including smartness in its technologies. Heat pump technologies are today’s solution for smart heating and key player for the future of heating and cooling.

Smart heat pumps can be tailored the consumers' needs, preferences and requirements by running at specific moments and/or specific conditions on the consumer’s request. Improving consumer comfort is a key driver of market demand.

[34] Thomas Nowak, (2018), Heat Pumps: Integrating technologies to decarbonise heating and cooling
[35] Thomas Nowak, (2018), Heat Pumps: Integrating technologies to decarbonise heating and cooling
[36] Stats.ehpa, last access on the 24.02.2021, http://www.stats.ehpa.org/hp_sales/country_cards/

2.3 Benefits of flexibility

Multiple benefits have been spotted for consumers who chose to adopt a flexible approach to energy and to society, such as:

1. The financial benefits from saving money on energy bills.
2. The possibility to increase the "environmental conscience" in the user, and then boost renewable energies application,
3. Consumer's proactive role and being independent from the grid, allowing a minor impact on the environment.
4. Increased demand-side flexibility could lead to savings of €5.6bn per year from reduced back-up capacity, network, and fuel costs in Europe.
5. Improved market conditions to ensure access to all flexibility options would directly translate into a reduction of wholesale electricity supply costs by around €50 billion in the year 2030.[37]

This can be seen in practice in the findings of a report published by Tennent, a Dutch Electricity transmission system operator in the Netherlands, who establishes that heat pumps and flexible heating systems could 'benefit countries with serious grid congestion'. By 2030 this could provide between '0.5 and 1GW of temporary flexibility'.[38] This example illustrates the potential of flexibility and the contribution of intelligent heat pumps in resolving congestion issues.

2.4 Key Issues

Whilst flexibility brings consumers and society several clear benefits, there are still some issues that should be considered in order to bring the user the best possible experience.

Issues facing consumer include:

1. Clear and easy to access information on the different tariffs and options. There is a specific need to present contracts with clear clauses and information, so not to confuse consumers.
2. Avoiding digital exclusion and providing to all European people equal opportunities as consumers, to avoid discrimination.
3. Aside from the possibility to facilitate services for flexible electricity consumption, there shall be attractive market prices for the products that provide flexibility. The combination of these two factors is fundamental for the consumers.
4. Ensure strong and efficient data protection and access to data. The parties that have access to consumer data, they shall not process more data than they need to deliver their services.[39]

[37] SMART ENERGY EUROPE (2019), A vision for smart and active buildings
[38] PV Magazine, (2019), Flexible heat pumps ideal for power grids congested by solar and wind, last access on the 04.03.2021
[39] BEUC, (2019), The future of energy consumers.

2.4.1 What about CyberSecurity & Data Protection

As discussed above, digitalisation and flexibility can greatly impact users' lives. Data has rapidly become one of the most valuable traded goods.

With the continuous digitalisation of the energy sector, energy data value and quantum are ever increasing. While digitalisation brings many positive benefits, it also makes energy systems more vulnerable to cyber-attacks.

Imagine the scale of the data that DSOs manage on electricity production and consumption. This information could be very valuable to certain actors while considered sensitive by the consumer.

Whether sensitive or not, it is important that consumers have full access and control of their energy data and whom it is shared with. As the owner of the smart meter, and thus responsible for a data source, the DSOs must be able to check its customers' consents for data processing before sharing any data with a third party. [40]

The data collected by the EMS in smart building is not only related to the energy consumption, but includes other measurements coming from sensors, smart meters, heat pumps, solar PV, etc... with values related to personal details, building or house metrics, and other sensitive information.

The collection and treatment of these data is of great concern to consumers; therefore, a strong EU policy regulation is needed.

Cyber-attacks are becoming easier and cheaper to organise, while digitalised equipment and the growth of the Internet of Things (IoT) increases the potential of cyber-attack in energy systems.[41]

The International Energy Agency (IEA) identifies some **practical solutions to prevent cyber-attacks** and provides some guidelines on how energy security should be built around three key concepts:

- **Resilience,** i.e., the ability of a nation, system or institution to adapt to changing contexts, to withstand shocks, and to quickly recover or adapt to a desired level of stability, while preserving the continuity of critical infrastructure.
- **Cyber hygiene,** i.e., the basic set of precautions and monitoring that all ICT users should undertake. This includes awareness, secure configuration of equipment and networks, keeping software up to date, avoiding giving staff and users unnecessary system privileges or data access rights, and training.
- **Security by design,** i.e., the incorporation of security objectives and standards as a core part of the technology research and design process."[42]

[40] E.DSO (2019), The E.DSO sustainable grid charter
[41] IEA (2017), Digitalisation and Energy, technology report
[42] IEA (2017), Digitalisation and Energy, technology report

Considering the above framework, it is clear to see that recent technologies bring new challenges. As well as considering the challenges of cybersecurity and data protection, we must also look at its environmental impact of the enormous amount of data stored in data centre.

Data centres:

The amount of data that needs to be captured, transferred and analysed is increasing and data centres are the main components of digitalisation and cloud computing.

In 2018 the energy consumption of data centres in Europe was 76.8 TWh, and this is expected to rise to 98,52 TWh by 2030 (with a 28% increase). In the EU, data centres accounted for 2.7% of electricity demand in 2018 and this is expected to reach 3.21% by 2030 (if development continues the current trajectory). [43]

The number of Data centres has grown due to the increasing demand for data processing. Furthermore, the size of data centres has increased, and there is an ongoing trend in the consolidation of data centres into larger entities.

Due to the data centre's considerable energy consumption, the European Digital Strategy sets a goal to achieve "climate-neutral, highly energy-efficient and sustainable data centres by no later than 2030". [44]

Considering the major role of data centres in the digitalisation revolution, there is a huge need to decarbonise this sector, and a possible solution could come with district heating application. In urban areas, data centres profile as a waste heat source of reliable, low temperature, high-capacity heat. Almost all the information and communications technology (ICT) electricity consumption can be converted into heat. New data centres can be designed with an ability to capture waste heat and distribute it to nearby customers, such as homes, offices, swimming pools or greenhouses. A heat reuse solution allows Data centres to sell the waste heat to a third party, such as a district heating operator. [45]

[43] European Commission, last access on the 05.02.2021
[44] European Commission, last access on the 05.02.2021
[45] Matti Pärssinen, Mikko Wahlroos, Jukka Manner, Sanna Syri, (2019), Waste heat from data centers: An investment analysis,Sustainable Cities and Society, Volume 44

2.5 Policy Framework

EU CYBERSECURITY ACT:[46]

The EU policy framework surrounding Cybersecurity saw its last regulation in 2017 within the Cybersecurity Package "Resilience and Defence: building strong cybersecurity for the EU". On this occasion, the European Commission reformed ENISA (the European Union Agency for Network and Information Security) and decided to promote a common certification framework.

The EU Cybersecurity Act establishes an EU certification framework for ICT digital products, services and processes. The European cybersecurity certification framework enables the creation of tailored and risk-based EU certification schemes. The need for conformity in certificating products and services is seen as a necessity to not fragment the EU internal market.

This certification framework will provide a set of rules, technical requirements, standards and procedures to be applied on EU-wide level. This will allow a common agreement and compliance with specific EU requirements, for ICT-based product or service.

In particular, each European scheme should specify:

- Categories of products and services covered,
- Cybersecurity requirements, for example by reference to standards or technical specifications,
- Type of evaluation (e.g., self-assessment or third-party evaluation),
- The intended level of assurance (e.g., basic, substantial and/or high).

To express the cybersecurity risk, a certificate may refer to three assurance levels (basic, substantial, high) that are commensurate with the level of the risk associated with the intended use of the product, service or process, in terms of the probability and impact of an incident.

There has been no release of legislative documents on the cybersecurity certification. In June 2019 the European Commission launched a call for stakeholders to provide inputs on the cybersecurity certification and support the EC and ENISA in preparing the work programme.

GENERAL DATA PROTECTION REGULATION (GDPR):[47]

Since May 25th, 2018, the General Data Protection Regulation (GDPR (2016/679)) imposes obligations upon organisations which collect and process personal data in the EU. GDPR focuses on the protection and processing of personal data, including processing, usage, storage and accuracy. GDPR does not address cybersecurity issues, critical infrastructures, or energy sector specificities. Jointly with the GDPR rules, the

[46] Eu Cybersecurity Act
[47] GDPR, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016R0679&from=EN

Directive 2019/944 regulates the processing of data in the energy sector. Consequently, end-users must sign an agreement to allow the access and treatment of their private data (ambient and consumption monitoring). Moreover, third parties that have access to energy management platforms should only operate with anonymized data.[48]

Personal data in the energy sector play an important role in the electricity grid management in terms of flexibility, energy mix and efficiently. Furthermore, the EU's objective is to convert 80% of electricity meters into smart meters by the end of 2020, the volume of personal data collected will sharply rise in the energy sector.

Consequently, compliance with the requirement of GDPR presents some challenges. With a specific treatment for smart meters, there is a specific discipline foreseen in the Electricity Directive, that embeds the GDPR provisions in these cases, stating that the Member States shall ensure the application of the safest communication protocols and barriers against cyber-attacks.

E-PRIVACY:

The **ePrivacy Regulation**[49] regulates the use of electronic communications and is intended to replace the Directive on Privacy and Electronic Communications (Directive 2002/58/EC). The current ePrivacy framework is qualified as *lex specialis* to the GDPR.

The ePrivacy Regulation is addressed to companies operating in the digital economy and shall identify additional requirements they need to respect while processing personal data.

On the 10th of January 2017, the European Commission adopted a draft regulation on privacy and electronic communication to replace the existing ePrivacy Directive. Originally, the ePrivacy Regulation was intended to apply from 25 May 2018 together with the GDPR, however, progress has been slow and the council only came to a hesitant decision (Germany and Austria abstained from the vote) on the text almost three years later, in February 2021. The Council and the European Parliament will now negotiate the final text.[50]

This regulation could have far-reaching consequences for the energy sector. "Almost all innovative business models in the energy sector are based on the processing of consumption, condition, and measurement data, collected by a wide variety of measuring devices which are not limited to smart meters installed on the consumers' premises. Such business models would be inconceivable without data collected through terminal equipment and devices."[51]

[48] DG Energy, PwC, Tractebel, (2020), Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal market.
[49] ePRIVACY Regulation
[50] Council of the EU, 'Press release: Confidentiality of electronic communications: Council agrees its position on ePrivacy rules https://www.consilium.europa.eu/en/press/press-releases/2021/02/10/confidentiality-of-electronic-communications-council-agrees-its-position-on-eprivacy-rules/
[51] ePrivacy energy coalition, (2018), Open coalition letter on the future of the ePrivacy Regulation: https://www.ehpa.org/fileadmin/user_upload/20181024_Open_Coalition_Letter_on_the_Future_of_the_ePrivacy_Regulation.pdf

3. EU INVESTMENTS IN DIGITALISATION

The European Union is investing greatly in digital transformation and demand flexibility, both in allocating funding to the technological development and in promoting them via regulations.

For example, in 2016 the European Commission, in the context of Energy for all European suggested an update of different directives, among others the "Electricity Directive" which calls for "the ability of the consumer to adapt their electricity consumption in response to the market signals".

In the list below we spotlighted the major investments foreseen in the upcoming years:

1. The Multi Financial Framework (2021-2027): 187.4 million euros are invested in "Single Market, Innovation and Digital".
2. Horizon Europe: Digitalisation is part of the second pillar and around 19 billion euros were addressed to "Digital, Industry and Space". This framework has underlined the importance of R&I in the digital sector and how the EU shall be a key enabler of digital technologies.
3. Digital Europe Programme: the European Commission proposed to allocate 9.2 billion of budget to specific shape and support the future digital transformation in Europe for the period 2021-2027. In this programme part of the money are addressed to strength AI, support and enforce cybersecurity, build up network of EU digital hubs.

4. HEAT4COOL PROJECT AS CASE STUDY

The Horizon 2020 **Heat4Cool project**[52] aims to develop an innovative, efficient and cost-effective HVAC bundle for building installations or retrofitting, targeting a 30% reduction in energy consumption in a technically, socially, and financially feasible manner. Various diverse technologies come together in that respect: solar driven adsorption heat pumps, photovoltaic assisted DC heat pumps, phase-change-material heat and cold storage systems, sewage water energy recovery and intelligent demand energy management via the SCI-BEMS. The technologies have been installed and tested in three residential demo sites in Valencia, Chorzow, Sofia and in one district heating application in Budapest.

In the three residential demo sites the heating and cooling technologies (adsorption heat pump, PCM storage, water tanks, solar and thermal panels, and DC heat pump) have been connected to the Self Correcting Intelligent - Building Energy Management System (SCI-BEMS), providing an efficient and cost-effective management of the Heating and cooling services in the buildings.

In the recent years we have assisted in a boom of smart thermostatic control released in the market. Nevertheless, most of them either lack the aspect of automated personalized control, handing over this direct decision to the occupant, or ignore energy efficiency aspects and fail to incorporate any grid considerations at the level of individual residences.

The SCI-BEMS module tested in Heat4Cool, was envisaged to be a lightweight, cost-effective energy management system that will co-optimize energy consumption and user comfort.

To achieve this goal, the SCI-BEMS was designed and developed according to the following principles:

- Use as basis open API communication standards and automation software,
- Allow for flexible realization and customization of the system functionalities according to the infrastructure available,
- Utilize off-the-self monitoring and control devices that are affordable and widely available,
- Employ custom developed cloud services for data analysis and remote energy management.

In more detail, the heart of the SCI-BEMS system is a communication gateway built on a Raspberry Pi board, equipped with a ZWave RaZberry antenna, and utilizing the Openhab open-source software (see Figure 6).

[52] The Heat4Cool project has received funding from the European Union's Horizon 2020 programme for energy efficiency and innovation action under agreement No. 723925. https://www.heat4cool.eu/

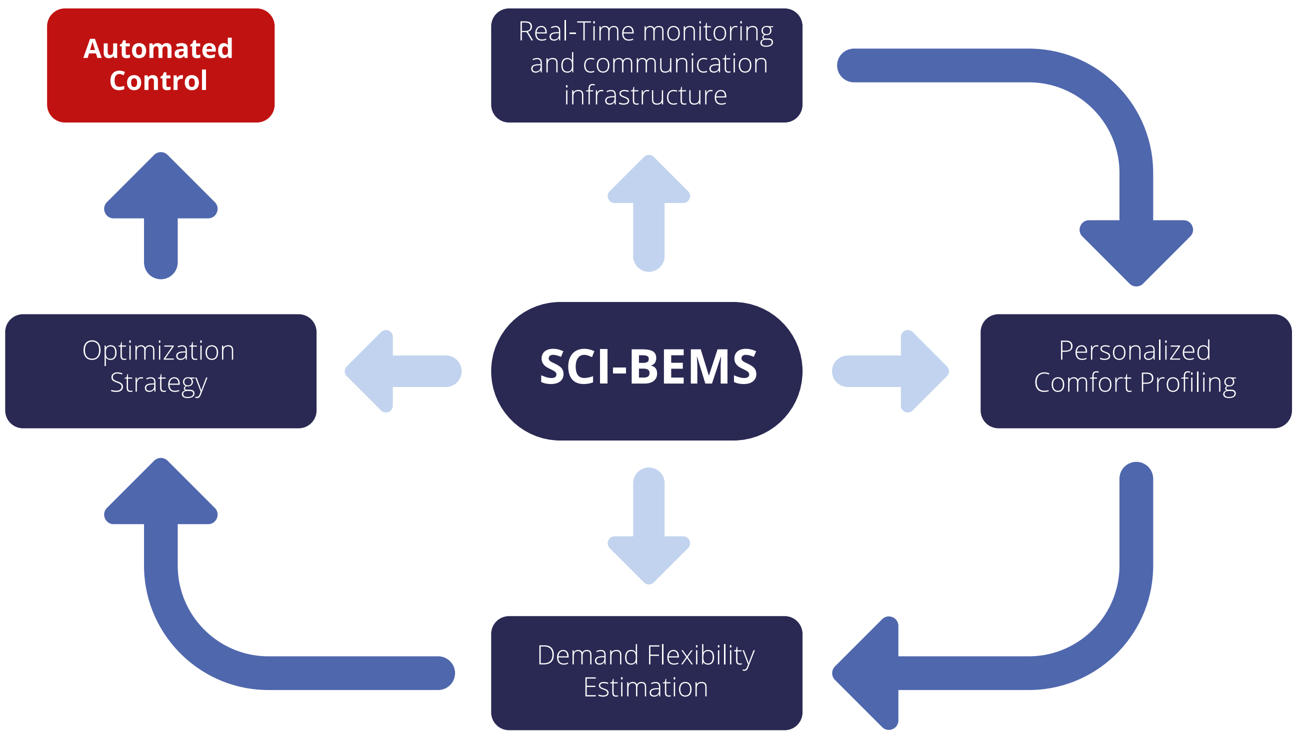


Figure 5. SCI_BEMS functional pipeline

The gateway collects information from sensing and thermostatic devices in a wireless fashion. Through these means, a significant amount of data characterizing the demand patterns are collected:

- indoor temperature and humidity,
- occupancy information,
- luminance,
- as well as preferred thermostatic setpoints and operation schedules.

The data are subsequently transmitted securely over the web to the cloud database and are enriched with weather data retrieved from available online services.
For privacy and security reasons, access to the database is restricted to only the data processors within the provider company. End users may request to receive copies of their recorded data at any moment.

Upon collection of the necessary data, they are analysed in batch, as well as streaming formats, to implicitly infer occupant preferences on indoor conditions. The process is automated and periodically scheduled to update these preferences based on the latest control actions (setpoint modifications, (dis)activation of HVAC) performed by the user, in correlation with indoor conditions at the time of such actions.

The process results in continuously up-to-date personalized user profiles that quantify personal thermal preferences vs. comfort trade-offs. Depending on the level of remote control possible, SCI-BEMS can then take over the operation of the system or suggest ideal setpoints to the end users.

These setpoints balance energy efficiency with occupant comfort. By doing this, SCI-BEMS adds the necessary demand-side

Figure 6. Technologies part of the SCI-BEMS

optimization step towards the efficient use of the innovative heating and cooling solutions installed. This demand-side management at the consumer/prosumer level, realized either as an energy efficient or demand response measure, is increasingly recognized as a more and more important aspect of any attempt towards energy sustainability, as has been highlighted in EU policy framework and EU goals mentioned in the above chapters.

As a result, the SCI-BEMS system, being an easily deployed, customizable and affordable energy management system, has a high replication potential across the whole European market thus to help end user in optimizing their heating and cooling services.

The SCI-BEMS combined with the sensors and the technologies installed in the residential demo sites (heat pumps, pcm storage, solar thermal and PV panels) are a concrete example of the benefits that the end users can have by adopting smart appliances and EMS, going from using their own electricity, saving money on the bills, and have suggested set-point ideal temperatures.

The combination of these innovative solutions brings a day-to-day support in the end-user's life and provides relevant input to support their energy management system.

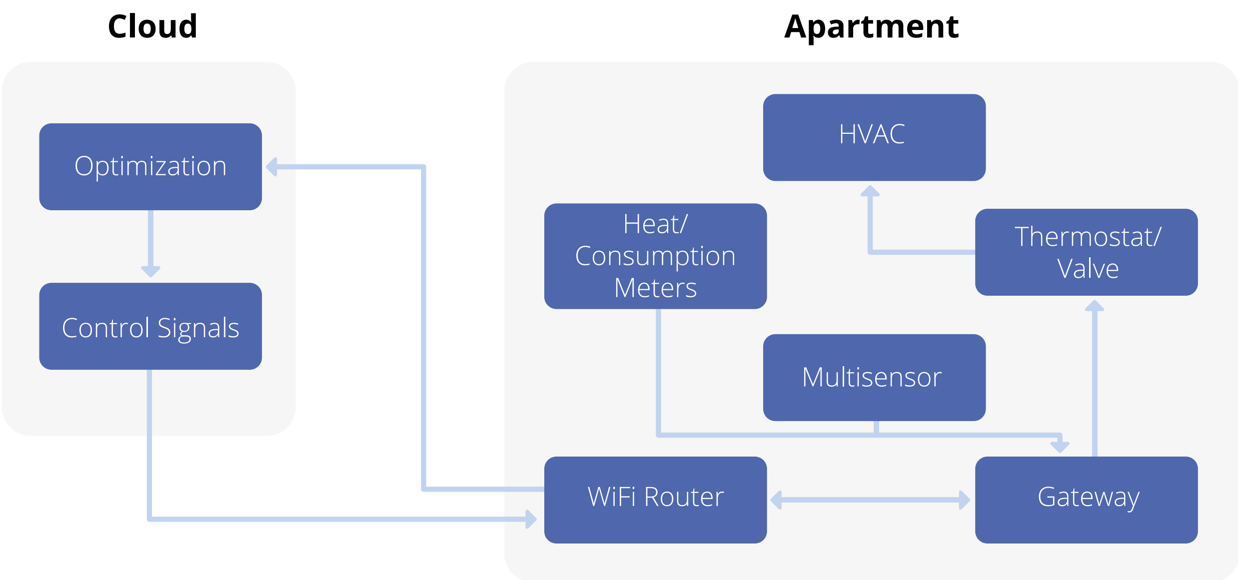
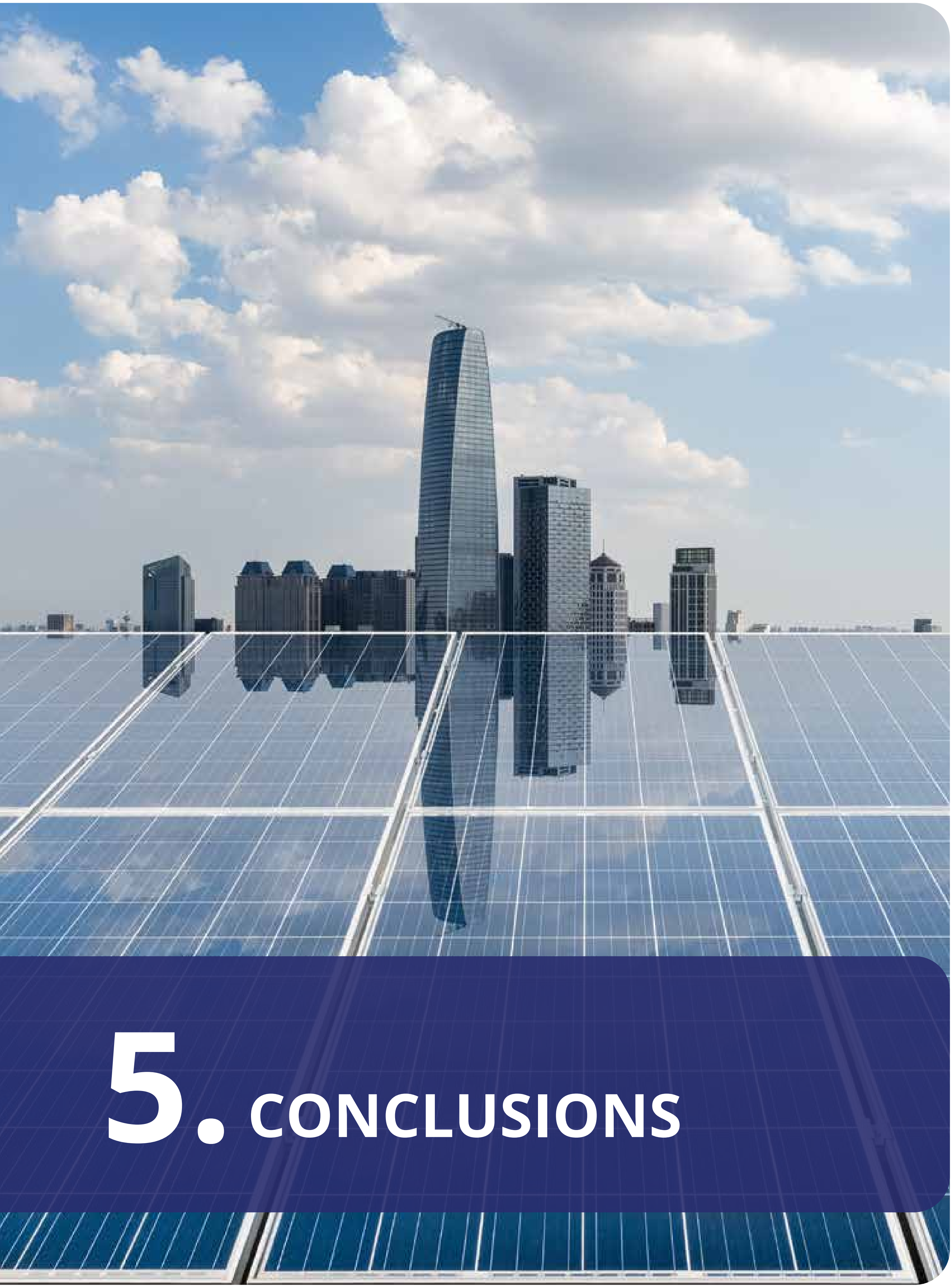


Figure 7. Sensors and Cloud Connections in the SCI-BEMS



5. CONCLUSIONS

Digitalisation is already making its mark on the heating and cooling industry and will continue to do so into the future.

Increased efficiency, higher shares of renewables, a cleaner environment, higher comfort, and reduced system cost are just a few of the benefits to industry, utilities, and end-users but also to society at large.

Making heat pumps (and other demand side technologies) integrated parts of the electric grid mandates digitalisation of the sectors products, components, and systems. The result: a renewable based, clean and efficient energy system that makes achieving Europe's energy and climate targets possible before 2050.

Currently market uptake and further development of integrated solutions is limited by distorted prices for energy.

- Using fossil energy in a rather inefficient way is still comparatively cheap.
- Flexibility is rarely given a value.
- Connecting components of a smart building is a challenge to the end user due to a lack of standardised solutions.

On a similar note, some of the challenges surrounding the digitalisation of the heat pump industry could and must be solved on a legislative level. Issues such as data protection and cybersecurity can only be decided in such a way, and by doing so would massively increase the uptake of digital solutions, and as already mentioned above, encourage innovation.

Both issues are of concern to many sectors not just in energy, and so government must stand alongside industry in order to solve these concerns.

In order to accelerate technological advancement policy makers, need to address the points raised above. A market environment conducive to innovation and growth should be a priority. Only then will a significant amount of brain capacity and capital be invested in the sector.

Digitalisation of heating and cooling will make the local benefits of heat pump technologies accessible and relevant to the building.

Developing this field further is not only exciting, but vital for an emission free Europe – well before 2050.

"A renewable based, clean and efficient energy system that makes achieving Europe's energy and climate targets possible before 2050."