Comfort & Climate Box – towards a better integration of heat pumps and storage

Final report of the combined Annex 34 (ECES) and Annex 55 (HPT)

Part VII – Roadmap

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Status:	Draft 0.6 – 7 December 2021

This report has been made available as part of the work under the combined ECES Annex 34 / HPT Annex 55 on heat pumps and storage. The opinions expressed herein do not necessarily reflect a consensus within the working group from Annex 55/34.

Contents

1 Introduction

According to IEA's recently published report "Net Zero by 2050 – A roadmap for the global energy sector" (2021) one of the defined key milestones, are "**no new sales of fossil fuel boilers by 2025**" and that "**50% of heating demand is met by heat pumps in 2045**". To fulfil this the stock of installed heat pumps needs to increase from 180 million units in 2020 to 600 million units in 2030 (more than triple) and thereafter a tenfold increase to 1800 million units in 2050.

The efforts made so far to support and stimulate improvement and deployment of heat pumping technologies have resulted in growing markets and more efficient products, but more efforts are needed. There are still many remaining barriers, but also a number of drivers that could be profited upon. Drivers and barriers are further described in Appendix 1.

For all regions of the world, it has been concluded that increased electrification of the building, transport and industry sectors is one of the main pathways to reach net zero carbon emissions, which requires a strengthened electricity system with zero net emissions of greenhouse gases.

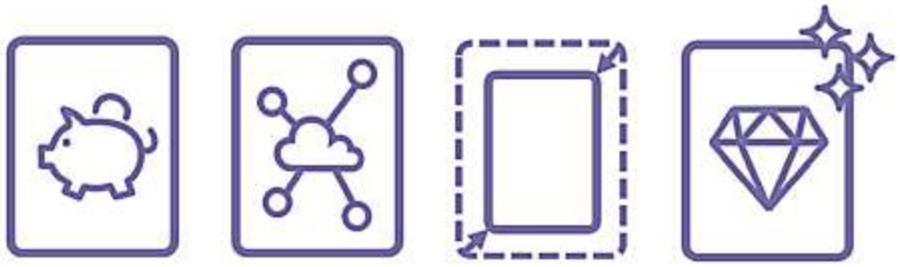
By combining heat pumping technologies in buildings with energy storages and integrated control, i.e **Comfort and Climate Boxes** (see further definition of the concept in Appendix 2), several issues may be tackled, such as

- Balancing and controlling electricity grid loads;
- Capturing a larger share of renewable (local/regional) input (i.e. solar thermal, solar PV);
- Optimizing economics, CO_2-emissions, fuel use throughout time;
- Providing optimal supply security to buildings;
- Providing smaller and cheaper heating systems.

To achieve these policy goals, several different *implementation strategies* for the CCB concept can be used.

Heat pumps and storage units are typically designed to give the best *energy efficiency*. That means: high COP, and low thermal losses. When looking at those components from a system perspective, the performance goals for a CCB may be extended beyond energy efficiency.

Four 'archetypes' for possible implementation strategies that form the focus and goal of CCB development have been defined by this Annex – Affordability (prioritizes low first cost); Flexibility (prioritizes the possibility to load shift); Compactness (prioritizes small size); Energy efficiency (prioritizes the efficiency of the product).



Affordability *Flexibility* *Copactness* *Energy efficiency*

Figure 1. Four archetypes for CCB implementations. From left to right: Affordability; Flexibility; Compactness; Energy efficiency.

Depending on the local conditions - the market maturity and which are the main drivers and barriers on the market in the actual country or region, different implementation strategies are recommended. This is especially important for policy makers, because the four archetypes can help to achieve different policy goals and support different use cases. The next step then is to establish a package of specific policy support measures, tailored to that strategy. The technical solutions are available already; our present task is to establish and develop new heat pump and storage markets.

2 Main recommendations

In many locations, the roll-out of heat pumps could be realized and accelerated if the heat pumps are integrated in Comfort and Climate Boxes (CCB), i.e. an integrated combination of heat pump, energy storage and control, designed to work together. However, depending on the actual main barriers and drivers in a particular location (country or region), different strategies are recommended to be implemented - Affordability, Flexibility, Compactness or Energy efficiency.

Recommendations for each of these four implementation strategies are listed below. In chapter 3 the recommendations are further elaborated and described from the perspective of different stakeholder groups.

2.1 Affordability

To realize a massive roll-out of heat pumps (integrated in CCBs or not), a market demand must be created. For this to happen there must, first of all, be a decent business case for the end consumer, in comparison to less sustainable competing alternatives, at least for the life-cycle cost.

In case the **running cost is too high**, in comparison to competing, less sustainable alternatives, the recommendations to *policy makers* are:

- To make a tax shift, to increase the tax on fuel that causes CO_2-emissions and decrease it on electricity or to introduce some type of fees or price for CO_2-emissions
- To create incentives, e.g. subsidies, to refurbish buildings to decrease the overall heating demand and thereby the running cost
- To incentivize flexibility, to make the use of energy storage more cost effective and attractive for the building owners

In case the running cost is low or acceptable, but the main barrier is **high upfront cost:**

- The recommendation to *policy makers* is to create and offer end consumers subsidies for investment in clean heating equipment.
- The recommendation to *utilities* and *manufacturers* is to offer alternative business models for using a heat pump or CCB as main heating equipment, e.g. rental schemes or leasing of equipment.

In case the **overall life cycle cost is too high** (no matter if it depends on high running or upfront cost) the recommendation to *manufacturers* is:

- To make the products "sufficient efficient", not add additional features to the product and focus on mass production of a limited number of models.
- Make the products "plug-and-play" to minimise installation and maintenance cost.

In addition, the recommendation to both *policy makers* and *manufacturers* is to

- Ensure capacity building, to educate installers as well as others in the value chain of Comfort and Climate Boxes.

2.2 Flexibility

A massive roll-out of heat pumps will in some locations create an additional pressure on the electric grid. To overcome this barrier, a solution would be to roll-out (a large share of the) heat pumps integrated in Comfort and Climate Boxes (CCB) focused on optimising flexibility performance.

If **available electric power capacity is an issue** at certain occasions, either due to lack of available production capacity and/or transmission capacity or due to a high share of renewable but intermittent production of electricity in the mix etc.

The recommendations to *policy makers* are to:

- Promote energy storage in buildings
- Develop and revise labelling schemes which promotes clean heating solutions which could balance the electricity grid
- Invest in electric infrastructure – both grid and production facilities of renewable electricity

The recommendations to *utilities* are to:

- Implement tariffs that stimulates off-peak-hour operation of the heating system and incentivizes reduction of electricity demand during peak hours
- Inform the end users or consumer organisations on how they can influence their energy bill by being a part of the electricity capacity market and incentivise to contribute demand-control/flexibility
- Use harmonized price structures (over regions and countries) and to not change the price structures two often, i.e. every year. The manufactures need to know which type of price structures they should develop control systems for.
- Investigate in new ways of funding of Comfort and Climate Box solutions like rental schemes, leasing etc
- Create a better link to installers of heat pumps and Comfort and Climate Box solutions

The recommendations to *aggregators* are*:*

- Investigate in new ways of funding of Comfort and Climate Box solutions like rental schemes, leasing etc
- Inform the end users or consumer organisations on how they can influence their energy bill by being a part of the electricity capacity market and incentivise to contribute demand-control/flexibility

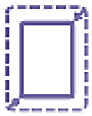
The recommendations to *manufacturers* are to:

- Investigate in new ways of funding of Comfort and Climate Box solutions like rental schemes, leasing, etc.
- Make control strategies for Comfort and Climate Boxes for combinations with solar PV and smart grid
- Make your products ”plug-and-play”
- Make your communication protocol standardized (open)
- Acquire more knowledge about energy storage and solar energy

The recommendations to *standardisation organisations* are*:*

- Develop standards for combinations of heat pumps, energy storages and integrated control
- Develop standards for communication protocols

2.3 Compactness



In some countries or regions, space constraint is one of the main barriers to increase user acceptance of heat pumps as heating equipment. To overcome this barrier, a solution would be to roll-out (a large share of the) heat pumps integrated in Comfort and Climate Boxes (CCB) focused on optimising compactness.

The main recommendations to *manufacturers* are to:

- Design the CCB as compact as possible
- “Boxify” the products, see 3.4 for further explanation
- Keep the volume of the energy storage limited and the possibility of using the building construction as heat storage should be utilized

2.4 Efficiency

The ‘Efficiency’ archetype, corresponds most closely to a traditional top-of-the-line heat pump / storage system found on the market today. The policy measures implemented so far have spurred the development of high-efficiency heat pumps, that are able to work in a wide operating range. This focus and implementation strategy has taken the technology to its present status, where it is well recognized by policy makers and recommended by IEA to be the most frequently used heating technology for buildings in a net zero emission scenario.

The other three archetypes, or implementation strategies, have so far less often been specifically targeted by research, product development, standardization or policy measures. Therefore, these implementation strategies need to get more attention in the future by all stakeholders.

2.5 Further recommendations

Besides of pure rational economic and technical arguments, there are other drivers and barriers for end consumers to select a heat pump – integrated in a Comfort and Climate Box or not, which need some

attention. On many places the awareness of climate change is increasing, but the knowledge of heat pumping technologies as one of the solutions might be low.

In case the awareness of the technology is low:

- The recommendation to *policy makers* is to invest in **information campaigns** to inform both end users, new business developers and investors.
- The recommendation to *manufacturers* is to inform end users that Comfort and Climate Boxes could be a multiservice provider – it could offer comfort - heating, hot water and cooling. In addition, it can improve the end users' possibilities to affect their heating/electricity cost. Moreover, it will decrease the end users CO_2 footprint.

3 Recommendations by stakeholders

This project has resulted in a set of recommendations, to overcome barriers and profit on existing drivers to realize the massive roll-out of heat pumps, and especially Comfort and Climate box solutions, needed to reach the climatic targets. In this chapter, the recommendations are outlined for different target groups/stakeholders and applies to all types of CCBs. The most important stakeholder, to realize the transformation are policy makers, utilities and manufacturers. In addition, it is of high importance to reach out to and inform, educate and train installers and other entrepreneurs. Aggregators, end users, standardization organizations and financial institutions do also have a role to play and should be informed about the possibilities Comfort and Climate Box Solutions offer.

As stated in the introduction of this report, depending on the local conditions - the market maturity and which are the main drivers and barriers on the market in the actual country region, different recommendations are more important than others.

3.1 Policy makers

To reach Zero Emissions to 2050 the stock of installed heat pumps needs to increase by a factor 3-4 to 2030 and tenfold to 2050, according to IEA's recently published Roadmap "Net Zero by 2050". Rolling out the heat pumps as an integral part of a Comfort and Climate Box, could facilitate this rapid necessary deployment.

Policy recommendations to stimulate the deployment of CCBs

To support and stimulate this process the following recommendations are given:

- Promote **energy storage** in policies.
  - Much of the renewable energy sources which we need to rely on in the future are intermittent and non-controllable – therefore different types of energy storages need to be used to a larger extent.

- **Develop and revise labelling schemes which promotes clean heating solutions which could balance the electricity grid.**
  - First of all, buildings should be labelled based on their **carbon emission (or based on used primary energy)**, not only for the energy efficiency of the construction.
  - Secondly, all heating systems should be compared on the same scale based on carbon emissions and/or use of primary energy.
  - Develop **labelling systems** for combinations of heat pumps, storage and control.
  - All labelling schemes relies on harmonized standards. Without appropriate standards, labelling schemes will not drive in the right direction. To stimulate and support the development of such standards, **fund prenormative research** (research which gives input to standardization organizations), especially for development of standards for **combinations** of heat pumps, storage and control.

- Invest in **information campaigns** to inform both end users, new business developers and investors.
    - It is important that all and everyone is informed about the necessary pathways to reach a sustainable future. Therefore, in information campaigned, acknowledge the electrification of heating buildings by application of heat pumps and Comfort and Climate Box solutions.
    - Preferably, the information campaigns should be based on results from pilot, demo or laboratory tests – to serve as proof of concept. Results should be translated to appropriate key indicators well understood by the target groups.

General policy recommendations to stimulate the deployment of all type of heat pumps (not only those integrated in CCBs)

- Make a **tax shift.** Today electricity is heavily taxed in many regions. Instead of taxing the energy carrier, the primary energy resulting in carbon emissions should be taxed or a fee or price should be associated to the emissions. It is very important that the tax structure support introduction of more renewable energy sources on the energy market, instead of being hurdles

- **Create long-time predictable incentives that stimulates increased use of renewable energy sources.** Besides making tax shifts according to the previous bullet other incentives which stimulate the use of renewable energy sources should be introduced, e.g. subsidies for investment of equipment, advantageous feed-in tariffs for on-site produced electricity, etc. However, to create a good business case for the investors (from households to investment banks) it is of importance that the incentives are **long-time predictable**. It is better with a moderate subsidy on long time basis compared to large ones on a short time basis. In addition, make it possible to have long term contracts for electricity (including feed-in tariff guarantees) to reduce the long-term uncertainty for investments

- **Create incentives to refurbish buildings.** Comfort and Climate Boxes/heat pumps works often very well in existing buildings, but a renovated building and a Comfort and Climate Box is a win-win solution, where the different measures gain from each other. Therefore subsidies/incentives for renovation for the building itself should be coupled with subsidies for heating systems

- **Promote and support education and training of installers.** The shortage of skilled installers is one of the biggest challenges to deploy the required high numbers of heat pumps (in CCB or not). This should be addressed by policy makers by supporting new forms of training or retraining of installers of fossil fuel boilers and/or unemployed.

- **Do not apply diversified policies in regions and countries.** Regulations for e.g. sound and refrigerants, that differ very much between different regions/countries could constitute unnecessary hurdles for companies and actors which develop, manufacture and install equipment which has an integrated heat pump, like a Comfort and Climate Box. Apply, as far as possible, the same policies globally, or at least in whole regions, like EU, America, parts of Asia

- **Develop up-to-date regulations and guidelines for flammable refrigerants.** Due to the European F-gas regulation and the Kigali agreement, there is a rapid development within the field of application of low GWP and natural refrigerants and many of them have higher flammability compared to traditional refrigerants – however often only mildly flammable. However, the development and adaptions of the regulations related to this new type of refrigerants and applications are lagging. To be able to roll-out this clean energy technology safely, without unnecessary hurdles, it is of importance that the regulations are up to date with the new refrigerants of today, based on evidence and knowledge

- **Revise property law to avoid lock in effects.** In many countries, e.g. Austria and Switzerland, the property law for buildings creates a hurdle for making an investment in a Comfort and Climate Box solution

Example 1: Phase out oil boilers through deployment of heat pumps –Swedish example

Heat pumps have largely contributed to the near complete phase out of fossil fuels for space and water heating in detached houses in Sweden, and for reducing greenhouse gas emissions by more than 90% since 1990. Ground source heat pumps are now a typical heating solution and equip a quarter of the houses, which is the highest penetration in the world.

The success factors behind this development are a combination of policy measures and other activities such as

- Continuous research, development and dissemination policy programmes for the technology since the 70's
- Suitable energy infrastructure and low electricity prices
- Tax on CO_2 resulting on high tax on heating oil
- Tax credits or tax reduction for installation of heat pumps (however relatively limited)
- Public financing of product testing, information and advice, which have been essential to create consumer acceptance and trust for a new technology
- Both the collaboration and the competition between manufacturers, e.g. collaboration regarding handling of consumer disputes
- Training of installers by manufacturers and trade organizations, later financed by the Swedish Energy Agency
- Collaboration between the energy agency and the heat pump industry at national and international level at the introduction of MEPS such as the Energy Label and Ecodesign requirements for space and domestic hot water heating
    - Dialogue and information meetings were arranged by the Swedish Energy Agency, which were attended by both industry and standardisation experts
    - The Swedish heat pump industry collaborated to formulate and coordinate comments on the regulations, on a national level as well as on an European level
    - The Swedish Energy Agency had already over many years regularly organized comparative tests, performed by RISE (former SP), of different types of heat pumps. Experiences from these tests made it possible to make relevant independent assessments of the proposed requirements, including threshold levels, during the development of the regulations

One of the main challenges ahead is the role of heat pumps in an energy system with an increased penetration of intermittent energy sources. Besides of ensuring high efficiency at low outdoor temperatures, heat pumps should have the ability to adapt to the heating demand of the building and its users behavior and the ability to interact with the electricity system, such as adaptation to real time electricity prices or to different load management signals. Beside these advanced control capabilities, thermal energy storage is crucial and should be further investigated and promoted. To overcome this challenge, it should be met by a similar (but identical) mix of policy and market measures as described above.

Reference

Lopes, C., Haglund Stignor, C., and Olsson, E., *Factors for enhancing the market development of energy efficient heat pumps – Scaling up through European policy*, ECEEE 2019 Summer Study on energy efficiency, 3-8 June, Presqu'île de Giens, France, Paper 9-359-19.

Example 2: Incentivizing Technology Adoption - Canadian Example

Providing an economic incentive to adopt a particular technology can drive increased market uptake while also fostering further innovation and economic growth in sectors related to the technology. The Canadian province of Ontario presents an interesting case study on how targeted policy programs can drive an increased adoption of renewable energy technology and spur economic development.

In 2009, the Ontario provincial government passed the *Green Energy Act*, which aimed to both increase renewable generating capacity and support investment and job growth in the clean energy sector [1]. This *Act* was primarily driven by two feed-in tariffs for small (MicroFIT, <10 kW) and larger scale (FIT, 10 kW - 500 MW) renewable energy installations. Successful applicants entered into a 20-year contract that guaranteed a fixed price for electricity fed into the grid [1]. While guaranteed purchase prices varied depending on the year, technology, and project scale, rates often approached 5-10 times the cost of purchased grid electricity, incentivizing many enterprises to become involved in clean energy generation. Initial calls for projects also implemented local content requirements that approached 50-60% of system components, helping to stimulate industry growth around the development and manufacturing of these technologies in Ontario [2].

The application of these policies has had a significant impact on the adoption of renewable energy technologies in Ontario. Since program inception in 2009, generating capacity from wind and solar technologies has increased from approximately 1300 MW to 6000 MW [2]. The financial impacts have also been significant, with nearly $11 billion CAD invested in wind and solar technologies, creating approximately 180,000 direct and indirect jobs in the solar and wind sectors [2]. Ontario now ranks among the jurisdictions with the highest investment in solar and wind generation. Despite these strong benefits, the high guaranteed rates established in the service contracts have also been linked with increased electricity rates for consumers [1]. This underlines the importance of a holistic approach to policy and incentive development, in order to increase the growth of renewable energy technologies and their associated industries while still ensuring accessibility and affordability at the consumer levels.

References

[1] Yatchew A., Baziliauskas A., 2011. Ontario feed-in tariff programs. Energy Policy 39(7), p. 3885-3893.
[2] Environmental Defence Canada, 2016. Getting FIT. Available at: https://environmentaldefence.ca/report/getting-fit/ [Accessed Dec 2020]

3.2 Utilities (electricity producers and grid operators)

Increased electrification of the buildings, transport and industry sectors as one of the main pathways to reach net zero carbon emissions, means both new business opportunities but also challenges for utilities. At a first glance, a massive roll-out of heat pumps could be a threat for some grid operators. However, combined with integrated, smart control and energy storages, this could be a real asset for grid operators. For electricity producers, increased deployment of heat pumps means new business cases.

Recommendations to utilities to stimulate the deployment of CCBs

The following recommendations are given to utilities:

- Implement **tariffs that stimulates off-peak-hour operation,** and **incentivize reduction of electricity use during peak periods**, of the heating system. By introducing such tariffs at an early stage, products that are able to operate economically under these conditions will be asked for by end consumers and developed by manufacturers.

- **Inform** the end users or consumer organisations on how they can **influence their energy bill** by being a part of the electricity capacity market and **incentivise to contribute demand-control/flexibility.** By increasing the awareness among end users and incentivised flexibility solutions, products that could offer end users to benefit from the electricity capacity market will be asked for, selected and purchased.

- **Investigate in new ways of funding** of Comfort and Climate Box solutions like **rental** schemes. By application of new ways of funding they can profit on the increased energy efficiency offered by a Comfort and Climate Box, while facilitating for end users to switch to a clean heating solution.

- **Create a better link to installers of heat pumps and Comfort and Climate Box solutions.** It is important that utilities find a way to make it beneficial for the installers to sell a Comfort and Climate Box solution instead of an ordinary heat pump.

- Be **stable** in time and use **harmonized** price structures (over regions and countries). This will make it possible for different actors to develop, sell and implement solutions that for example reduce peak demands or increase the share of self-consumption of on-site produced electricity.

General policy recommendations to utilities to stimulate the deployment of all type of heat pumps (not only those integrated in CCBs)

- **Invest in electric infrastructure – both grid and production facilities of renewable electricity.** To enable a massive roll-out of solar PV, heat pumps, electric vehicles the grid needs to be reinforced and new investment in production facilities are needed. This is a necessity to enable the electrification pathway to reach the climatic targets. However, this pathway will also offer many new business cases for utilities, electricity producers and grid operators. By stimulating that Comfort and Climate Box solutions are selected before conventional heat pumps the need to strengthen the grid could be limited to some extent and on-site electricity production could be promoted.

3.3 Aggregators, including social aggregators

An aggregator is a new type of energy service provider which can increase or moderate the electricity consumption of a group of consumers according to total electricity demand on the grid. An aggregator can also operate on behalf of a group of consumers producing their own electricity by selling the excess electricity they produce. This new type of actor will probably get an important role in the years to come in a transformed sustainable energy system. Aggregators could benefit if a large fraction of the heat pumps put on the market are deployed as Comfort and Climate Boxes.

Recommendations to aggregators to stimulate the deployment of CCBs

- **Invest in equipment and develop and offer rental schemes** for Comfort and Climate Box solutions to end user. By application of new ways of funding, like rental schemes, they can profit on the increased energy efficiency offered by a Comfort and Climate Box, while facilitating for end users to switch to a clean heating solution by making the investment themselves and let the end user rent (or lease) the equipment. Offer to the end user that they can get a lower rental cost if they let the aggregator operate the equipment while ensuring comfort for the end user.

- **Inform** the end users or consumer organisations on how they can **influence their energy bill** by being a part of the electricity capacity market and **incentivise to contribute demand-control/flexibility.** By increasing the awareness among end users and incentivise flexibility solutions, products that could offer end users to benefit from the electricity capacity market will be asked for, selected and purchased.

3.4 Manufacturers

Increased electrification of the buildings industry sectors as one of the main pathways to reach net zero carbon emissions, requires a massive roll-out of heat pumps within the next decade. This offers a huge business opportunity for heat pump manufacturers. However, to make the best of this opportunity and not spoil it, it is of vital importance that manufacturers develop and promote future safe products, and not only what the end users ask for today.

Recommendations to manufacturers to stimulate the deployment of CCBs

- **Make control strategies for Comfort and Climate Boxes for combinations with solar PV and smart grid.** To give your sustainable products the best possibilities for the future, it is of importance that they are compatible with other renewable, sustainable energy sources like solar energy and wind power. Prepare your system for more input signals and prepare you system to be Smart Grid Ready.
- **Make your products ”plug-and-play”.** Make your product as easy to install as possible, to avoid faults in the field. It should be **beneficial for the installer to aim at installing as many** Comfort and Climate Boxes as possible instead of putting many ours on one, with an uncertain end result. As far as possible, aim at making your products **self-optimizing and self-fixing.** Collaborate with digitalization specialists to make use of the latest technology. In addition, it is important to guarantee that cyber security is ensured. Find ways to **make it beneficial** for the **installers** to sell a Comfort and Climate Box instead of a plain heat pump or gas boiler.
- **Educate your installers and representatives** on the benefits of these system, and their proper selection, sizing, and integration.
- **Make your communication protocol standardized (open).** A large fraction of the heat pumps to be sold on the market should be smart and/or integrated in Comfort and Climate Box, in order to avoid unnecessary pressure on the grid and instead constituting a balancing asset. Collaborate with others, such as manufacturers building services engineering equipment, grid operators and aggregators.
- **Investigate new ways of funding** of Comfort and Climate Box solutions like **rental** schemes (e.g. in the Netherlands) and collaborate with utilities and aggregators. By application of new ways of

funding they can profit on the increased energy efficiency offered by a Comfort and Climate Box, while facilitating end users to switch to a clean heating solution.

- **Acquire more knowledge about energy storage and solar energy.** To give your sustainable products the best possibilities for the future, they should in many cases be combined with on-site energy storages and electricity (or heat) production from the sun. Therefore, it is important that the knowledge about these technologies, such as electric and thermal storage (do not forget cold storage) is secured inhouse.
- **"Boxify" all your products.** Do not underestimate how much it could increase user acceptance and facilitate for installers if the products are delivered as a "box"
- **Ensure solutions are well adapted to the local market.** For example, in North America, air-based distribution systems are common

General policy recommendations to stimulate the deployment of all type of heat pumps (not only those integrated in CCBs)

- **Offer tailored services to clients**
  - Some clients prioritize some properties before others when it comes to their comfort (heating and cooling) solution, some clients have the possibility to make their own investment, others prefer a leasing/rental solution – make sure you have an offer that suits them all (at least most of them).
  - The efficiency should be adapted to the different climates, optimize the efficiency for outdoor temperatures and heating(cooling) demands where most of the operating hours belong.
  - **Sell comfort** and not only a product for the heating – use the possibility that a heat pump (integrated in a Comfort and Climate Box or not) can offer cooling as an USP, on contrary to all type of boilers.
- Develop the appropriate systems **for air-based system** if you are aiming at putting your product on the market in America.

3.5 Standardization organizations

On most markets/regions energy labelling or MEP (minimum efficiency performance) regulations apply to heating and cooling solutions – often mandatory. This is beneficial for heat pumps and Comfort and Climate Box solutions, since they offer a better energy efficiency than conventional heating solutions. However, the fundament of all labelling schemes are harmonized standards. To promote that sustainable future safe products are put on the market, appropriate standards must be developed and revised.

Recommendations to standardization organisations to stimulate the deployment of CCBs

- **Develop standards for combinations** of heat pumps, energy storages and integrated control. Today only standards for separate equipment/products exist.
- **Develop standards for communication** protocols. To ensure a sustainable, robust and flexible energy system for the future it is a necessity that all (or as many as possible) systems interacting with the electricity system are able to communicate with each other.

General policy recommendations to stimulate the deployment of all type of heat pumps (not only those integrated in CCBs)

- **Develop standards for measuring/evaluation of installed** systems. To be able to assess how the products perform in real installations, and compare performance of different installations, it is of importance that they are evaluated in a standardized way. With improved knowledge of how products and systems works in real installations, products could be developed and redesigned in the right directions

3.6 Entrepreneurs and installers

This target group should first and foremost be informed by manufactures, utilities and aggregators about the **possibilities a Comfort and Climate Boxes could offer** – for them and for their clients. They should be informed about that, together with renovation (which should be done anyway or already have been done) the required heating system temperature will be low enough for heat pumps and Comfort and Climate Boxes.

Business organisation (for installers) should develop dimensioning programs to give rough guidance on heat pump size, storage size and type and size. More precise dimensioning programs are often offered by the manufacturers, but a common program could facilitate the selection of offering a client a heat pump based heating solution instead of a fossil fuel boiler.

3.7 End Users

End user should first and foremost be aware of the urgency - climate change must be mitigated by transforming the energy system now. Actions must be taken immediately and cannot wait to save the future.

- **There a several reasons for buying a Comfort and Climate Box as your heating solution.** They are good for the environment, they offer comfort, they are cost beneficial, and they are resilient.
- Consumer organisations should **bundle demand/requests from consumers.** This should provide consumers with the correct information and limit the risk for end consumers.

3.8 Financial institutions

By channelling private investment to the transition to a climate-neutral economy, as a complement to public money, the energy transition can be accelerated. To invest in energy efficiency measures and renewable energy often offer a predictable and low risk, which is appreciated by investors.

In order to be able to make a secure, low risk investment, investors are recommended to first and foremost put more attention to the buildings energy sector and explore its possibilities.

Recommendations to financial institutions to stimulate the deployment of CCBs

- Develop more attractive **funding schemes for sustainable** building energy solutions. Rate the risk of the investment differently (lower) compared to traditional energy solutions. Apply green premium and brown penalties for their clients.

Example 1: Sustainable finance – EU classification system for green investments – Taxonomy – European Green Deal

The EU has set climate and energy targets for 2030, and aims to be climate-neutral by 2050. EU classification system for green investments – Taxanomy creates a classification system for sustainable economic activities ('taxonomy'), and focuses on the EU's environmental objectives on climate change mitigation and adaptation. This will create a common language that investors can use everywhere when investing in projects and economic activities that have a substantial positive impact on the climate and the environment.

Sustainable finance is a work stream aimed at supporting the European Green Deal by channelling private investment to the transition to a climate-neutral economy, as a complement to public money.

The Taxonomy Regulation, Regulation (EU) 2020/852, was finally approved in June 2020 and a draft delegated regulation for "establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives" were published in November 2020. However, this delegated regulation has not yet been approved.

It is of uttermost importance that heat pumping technologies in general, and also integrated with storage and control are appropriately referred to in this delegated regulation, to unlock the potential of private investment to stimulate the deployment of this sustainable technology.

4 Process

During the first phase of the work within this Annex, the state of the art and present market situation for heat pumps, energy storage and Comfort and Climate boxes was described for all the participating countries. This all served as the first input for mapping and categorizing existing drivers and barriers for Comfort and Climate Box solutions.

In the next step interviews with the participants of the annex, country per country, were performed. During those interviews, drivers and barriers were discussed further and possible recommendations to overcome barriers and to profit on existing drivers were discussed. The annex participants provided input from different stakeholders in their respective countries.

Later during the Annex work, presently available standards related to Comfort and Climate Box solutions were mapped. In addition, a literature study of research work related to CCBs was performed, and results and lessons learned from simulations and field trials, earlier or performed within the annex, were compiled and described. This all served as input when outlining the recommendations.

Thereafter the preliminary barriers, drivers and recommendations were presented to and discussed within the whole annex group. The discussions were followed up by a survey sent out to the annex participants, where they could rank the importance of the different drivers, barriers, recommendations and stakeholders (target groups for the recommendations).

Based on all the input collected and compiled, the final versions of the recommendations were outlined.

Appendix 1 – Drivers and barriers

Integrated systems consisting of heat pumps, storage and controls, such as a Comfort and Climate Box solution, are in general considered as an important technological option to accelerate the deployment of renewable energy in the building sector.

Commercial development of this type of solution is progressing very slowly. Therefore, existing – or possible - drivers and barriers for the development and deployment of this type of solutions have been identified and categorized.

Some of the drivers and barriers apply to separate heat pumps (e.g. such heat pumps that are working only in space heating without any specific interaction with any energy storage or the grid) as well as to heat pumps integrated in a Comfort and Climate Box solution, some of them apply especially to Comfort and Climate Box solutions and some of them apply to separate heat pumps, but less to Comfort and Climate Boxes.

To stimulate a massive roll-out of heat pumps, integrated in Comfort and Climate Box solutions or not, a demand must be created as a first step. A viable business case for the end user, at least considering the life cycle cost, is often the first thing to be secured. The demand could thereafter be boosted by other qualities such as sustainability, security or comfort aspects.

However, even in cases where the life cycle cost is beneficial for the technology solution, a hurdle could be high upfront cost, which could be overcome by introduction of new business models. In addition, there could be several legislative and administrative barriers.

In any case and in any country, it is important, for policy makers as well as for market actors, to first identify which is the most predominant barrier to be overcome and which are the most important drivers to be profited on. In the following sections, barriers and drivers have been sorted in accordance with priority *for most of the countries* participating in this annex.

4.1 Policies

4.1.a Drivers

Apply especially to CCBs	• Directives and regulations which promote dynamic electricity prices • Strong support from authorities for Grid Interactive Efficient Buildings (e.g. recast of EPBD Smart readiness indicator)
Apply to separate heat pumps and CCBs	• **Electrification pathway in the national/EU strategy** • Goals to be carbon neutral / decarbonization goals/ decrease fossil fuel and to increase the share of renewable energy • Carbon taxes – existing or on the way (e.g. SE) • Ban for new gas connections (e.g. NL) • Tax deduction or subsidies for heat pumps • Policy for energy efficiency or decarbonization in buildings • EU regulation – sector coupling strategy • Recast EPBD Smart readiness indicator • Recovery support post Corona should be “green”

4.1.b Barriers

Apply especially to CCBs	• Subsidies are for technologies (separate) no common system • Diversified regulations in different part of the country
Apply to separate heat pumps and CCBs	• Taxes on electricity vs taxes on gas – promotes gas • Much focus on hydrogen • Sound regulations

4.2 Energy Markets

4.2.a Drivers

Apply especially to CCBs	• New tariff structures for on-site produced electricity with no net metering and large difference between feed-in and feed-out tariffs • Instability of the electric grid, an increasing awareness that solutions must be found • Load shifting, by peak shifting, means savings for the utility • Smart tariffs, to integrate more renewable energy into the energy system and to manage the grid, are being discussed • Capacity (or power) tariffs are getting more and more common • A strong market for solar thermal systems for DHW (Domestic Hot Water) heating • Thermal energy storage water tanks are common

4.2.b Barriers

Apply especially to CCBs	• Utility rate structures for residential buildings do not incentivize demand response behavior. • Much emphasis on electric storage (incentives, subsidies and/or investments) • No consistency in electricity and power (capacity) pricing, varying over time, differs from time to time, from place to place.
Apply to separate heat pumps and CCBs	• Ration of electricity price vs natural gas price is high (some countries)
Apply to separate heat pumps, but less to CCBs	• Capacity (power) tariffs (not beneficial for heat pumps) • Too weak electricity grid, e.g. max 3 kW power (less barrier for CCB compared to heat pump) (e.g. IT)

4.3 Standards

4.3.a Drivers

Apply to separate heat pumps and CCBs	• Standards for variable capacity-controlled heat pumps – a driver for more efficient products and a good start for standards for CCB. • Simplification in showing the results for heat pumps from standards, Energy Label or Energy star

4.3.b Barriers

Apply especially to CCBs	• No existing standards or labelling schemes (e.g. EU Energy Labelling or US Energy Star) for CCB, only for separate heat pumps • No current definition or standard for smart grid ready systems
Apply to separate heat pumps and CCBs	• Energy building labelling covers only consumption, not emissions • Old standards for flammable refrigerants. • Process time to develop standards

4.4 Communication protocols, internet connection

4.4.a Drivers

Apply especially to CCBs	• New heat pumps are sold with the possibility to internet connection and some manufacturers • There is already a smart meter infrastructure, a large fraction of residential households is already included • Remote control of heat pumps is possible and have been done in field trials (but still only on experimental level) • A number of better open and/ or bi-directional communication protocols approaches exist.

4.4.b Barriers

Apply especially to CCBs	• No harmonized communication protocols. • The existing "Smart grid readiness" standard, is very limited, only one-directional communication. • Reluctance among end users to have their energy consumption connected to the internet

4.5 Research and technology development

4.5.a Drivers

Apply especially to CCBs	• Some big manufacturers offer systems for integration of heat pumps with other systems; communication with solar PVs or the grid. • High knowledge about thermal storage and much ongoing research in universities (in water as well as in other systems such as Phase Change Materials) • Several ongoing research projects aiming at developing integrated control. • F-gas regulation drives towards using propane as refrigerant in heat pumps. Propane offers high temperatures, which is an advantage when combining the heat pump with thermal energy systems.

4.5.b Barriers

Apply especially to CCBs	• Appropriate control strategies (for grid interaction of combination of technologies) are not yet fully developed. • Lack of understanding/ knowledge about the impact of lifetime for a heat pump when its control interacts with an energy storage or the grid.

	• Sufficient knowledge about compact storage is still missing. • It is still difficult to measure/assess/determine the state of storage. There is still a need to develop tools and methods for this. • Lack of research on cooling storage
Apply to separate heat pumps and CCBs	• High noise levels from heat pumps (e.g. NL) • Low efficiency at low outdoor temperatures (e.g. CA) • F-gas regulation, need to develop new products

4.6 Installation and suitability

4.6.a Drivers

Apply especially to CCBs	• Shortage of skilled workers – driver for plug-and-play CCBs
Apply to separate heat pumps and CCBs	• Digitalisation, augmented reality could be tools to facilitate installations • Building improvements, renovations, are ongoing (makes heat pumps even more suitable) • Packages of fabric (insulation) and heat pumps are under development

4.6.b Barriers

Apply especially to CCBs	• Too few skilled installers, especially for combinations with storage systems and ICT • Air-based heat distribution systems (in US and Canada)
Apply to separate heat pumps and CCBs	• Design practices, standards and regulations concerning installation are missing • High temp heating system (UK) • Poor building fabric, not well insulated (UK) • Lack of space (urban area) (AT, UK) • Construction industry conservative – promote traditional systems, i.e. gas • Complicated, often expensive installation process (e.g. IT, CA)

4.7 Entrepreneur awareness

4.7.a Drivers

Apply especially to CCBs	• Some like to sell “expensive devices”
Apply to separate heat pumps and CCBs	• Incentives for energy efficiency in buildings - if you improve the class, you can get subsidies that ”pay for the installation” (e.g. IT) • If heat pump company is contacted directly when buying a heat pump this ensures good match between end user demand and company offer (e.g. TR)

4.7.b Barriers

Apply especially to CCBs	• No awareness to promote a CCB-type of system • Entrepreneurs generally focus more on selling luxury products than efficient and sustainable ones.

Apply to separate heat pumps and CCBs	• Lack of awareness that if you renovate the building the temperatures from a ”normal” heat pump is sufficient, the old radiator can be used. • First cost too high for heat pumps in general

4.8 End user awareness, acceptance and behaviour

4.8.a Drivers

Apply especially to CCBs	• The CCB concept offer a compact solution, since the components are design to be integrated. • Big push for solar PVs favors combinations with solar PV • The energy cost can be improved (reduced) by the CCB-concept since one can better profit on the tariff structure. • General awareness of challenges with the electric grid (black outs etc.) • Growing time dependent rate for electricity • Many heat pumps today are possible to connect to the internet.
Apply to separate heat pumps and CCBs	• Fridays for Future – awareness about climate change • Market for heat pumps is expected to/need increase to reach climatic goals • New neighbourhood development with no gas connections (e.g. NL) • Interest in reducing household energy use • Cooling demand in most parts of the country (e.g. CA, US) • Mature heat pump market, high acceptance (e.g. SE)

4.8.b Barriers

Apply especially to CCBs	• Few consumers have an electricity contract giving price variations per hour. • Few incentives for energy flexibility • People are not aware of possible problems in the future related to instability of electricity grid. • Lack of habit/experience with DHW (Domestic Hot Water) storages • Cybersecurity •
Apply to separate heat pumps and CCBs	• Lack of awareness of CCB solutions, for some countries also heat pumps • High upfront cost/investment cost • High running cost (e.g. IT, CA, UK, DE, BE) • People tend to move every five years (e.g. US) • Investment decisions are different if you own the building or not • Space constraints (e.g. IT, NL, CA) • Reluctance to flammable refrigerant