Technology Collaboration Programme
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Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 55

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

Final Report – Part 2

Market Status in Participating Countries

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Preface

This project was carried out within the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), which is a Technology Collaboration Programme within the International Energy Agency, IEA.

The IEA
The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of nearly 40 Technology Collaboration Programmes.

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)
The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) forms the legal basis for the implementing agreement for a programme of research, development, demonstration, and promotion of heat pumping technologies. Signatories of the TCP are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the TCP, collaborative tasks, or “Annexes”, in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex.

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A central role within the HPT TCP is played by the Heat Pump Centre (HPC).

Consistent with the overall objective of the HPT TCP, the HPC seeks to accelerate the implementation of heat pump technologies and thereby optimize the use of energy resources for the benefit of the environment. This is achieved by offering a worldwide information service to support all those who can play a part in the implementation of heat pumping technology including researchers, engineers, manufacturers, installers, equipment users, and energy policy makers in utilities, government offices and other organizations. Activities of the HPC include the production of a Magazine with an additional newsletter 3 times per year, the HPT TCP webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) and for inquiries on heat pump issues in general contact the Heat Pump Centre at the following address:

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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 II – Market Status in Participating Countries

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Contents

1 Introduction

This report gives and overview of the market status regarding CCBs in all participating countries. It is based on the input from the participants and discussion in working group meetings. The main focus is on providing the background on the CCB market, but also to 'rate' markets based on the nine quality criteria[1] and find optimal implementation strategies. Much of the information presented here depends on the personal knowledge and judgements of the contact persons from each Annex participating country. As such, the contents of this report should not be taken as official policy statements from the respective countries.

2 Market overview

2.1 General challenges and opportunities

The challenges and opportunities that would speed up and strengthen CCB in the relevant markets have been described in country reports provided by the participants. Table 1 below summarizes the market challenges and opportunities from these reports into categories.

Table 1 – Challenges and opportunities for CCB market development.

Challenges	Opportunities
Economic	
• Low cost for gas and boilers • Fluctuating gas prices • Rising electricity prices • High cost for imported heat pumps	• Low electricity price
Political	
	• Policy drivers • R&D support for heat pumps and energy storage • Increased pressure on the government to decrease natural gas-dependency
Technical	
• Noise	• Technical developments enabling quicker and easier installation
Power generation	
• Regional variation of carbon content in grid	• Transformation from large to small power plants • Transition to renewable power generation • Large difference between peak and valley power grid
Awareness	
	• Increasing awareness of fossil fuel risks • Strong solar thermal market for domestic hot water. Pre-fabrication for building market

[1] See Part I of the Annex documents for details on the quality criteria and implementation strategies.

2.2 Policy framework

Existing international and national policy drivers are the most powerful opportunity to stimulate and develop the CCB market. Existing policy frameworks for CCB markets are summarized based on the country reports in Table 2Table 1 below.

Table 2 – Policy frameworks for the CCB market.

Region/Country	Name	Level of regulation	Coverage
EU	Green Deal (2020)	Strategy	Global plan for accelerated implementation of carbon reduction measures
	Buildings Directive (EPBD)	Legislation	All new buildings have to be nearly zero-energy buildings (nZEBs) by the end of 2020
Austria	Carbon Neutrality	Strategy	To be carbon neutral by 2050
	Phase out oil and gas	Strategy	Phase out of oil and gas for heating by 2035 and 2040, respectively.
	Mechanical Ventilation with Heat Recovery (MVHR)	Subsidy	Improve the quality of buildings and to apply efficiency measures
	Alternative technologies	Subsidy	Heat pumps and renewables (ST or PV)
	Austrian Institute of Construction Engineering (OIB) Guideline 6	Guideline	Requirement on space heating demand and on the total energy effiiency factor (fGEE path), and other choise is EEB path which is defined as stricker requirements on space heating and on final energy demand.
Canada	Carbon Neutrality	Strategy	To be carbon neutral by 2050
	Market Transformation Roadmap	Roadmap	Framework for an increased adoption of high efficiency mechanical systems needed to drive decarbonisation of the built environment
Italy	National Energy Strategy 2017	Strategy	Recommends increase of renewable energy penetration by means of HP usage.
	National Energy and Climate Plan	Scenario	Heat pumps will double their gross final consumption by 2030, with respect to 2017, reaching 5.6 Mtoe.
	Conto termico 2.0	Incentives	Small installations to produce thermal energy from renewable sources or to save primary energy
	Tax deductions	Incentives	65% - 50% tax deductions favoring HP usage in building refurbishments
	White Certificates or Energy Efficiency Certificates	Incentives	private companies employing novel energy savings solutions (compared to the baseline state-of-the-art technologies)
Netherlands	Building regulations	Legislation	Forbidding the use of natural gas heating for new houses

Region/Country	Name	Level of regulation	Coverage
	Carbon-neutral built environment	Roadmap	Communities *must* make plans for completely emission-free heating for all houses and buildings in 2050. 20% of that goal to be reached in 2030.
	Energy Taxes	Incentives	Enhancing HP end-user with the energy taxes shifted from electricity to gas
	Investment Subsidy for Renewable Energy	Incentives	Covering up to several thousand Euro of the investment for heat pumps
Sweden	Fossil Free Sweden	Roadmap	Making Sweden climate neutral by 2045, 50% more efficient energy use by 2030, 100% power from renewable sources by 2040
	Carbon Tax	Incentives	2020 the tax is SEK 1190 (EUR 110) per ton fossil CO2 emitted
	CEN HP Keymark	Energy Labeling	Raising consumer awareness and confidence about heat pumps
	Electricity Certificates	Incentives	Instrument to increase the production and use of renewable electricity
	Tax Reduction	Incentives	Micro producer of power from renewable sources can get a tax reduction
Turkey	Energy Efficiency Strategy (2012-2023)	Strategy	Reducing energy use in buildings and CO2 emissions, increasing share of renewables and sustainable buildings
	National Energy Efficiency Action Plan (2017-2023)	Strategy	Efficient regional heating and cooling, extension of renewables in buildings
	Energy Efficiency Law (5627)	Law	Requires efficient heating and cooling
	Renewable Energy Law (5346)	Law	Use of renewables for power generation
	Building Energy Performance (BEP TR)	Legislation	Efficient heating, use of renewables affects the class of the building
	Energy Efficiency Regulation	Legislation	Efficient heating, cooling, Requires use of renewables in buildings where possible
	Green Buildings	Legislation	Existing and new buildings
	Feed-in-Tariff	Incentive	
	Green Tariff	Incentive	Consumers can choose to use electricity produced from renewables
UK	Committee on Climate Change	Strategy	Legally binding target to achieve net zero greenhouse gas emissions from across the UK economy by 2050
	Renewable Heat Incentive (RHI)	Incentives	Lowering barriers to the take-up of low carbon heating and cooling and sustain a viable supply chain for heat pumps

Region/Country	Name	Level of regulation	Coverage
	Future Homes Standard	Standard	New build home will not be able to use gas by 2025. Replacing an existing gas boiler in an existing home will be still allowed
USA	California Assembly Bill –AB2541 (2003)	Legislative	Encourage to incorporate energy storage into the electricity grid.
	Federal tax credits and other financial incentives	Incentives	Purchase and installation of electric heat pumps (ground and air source) and heat pump hot water heaters for residential, commercial and industrial buildings
	California Energy Commission	Strategy	Multitude of benefits for Energy, including supporting the integration of more renewable energy into the electric grid, deferring the need for new fossil-fueled power plants and transmission and distribution infrastructure, and reducing dependence on fossil fuel generation to meet peak loads.

2.3 Heating market

The current share of different energy resources used to meet heating demand in participating countries is given in Figure 1. Other aspects of heating systems in participating countries are summarized in the following paragraphs.

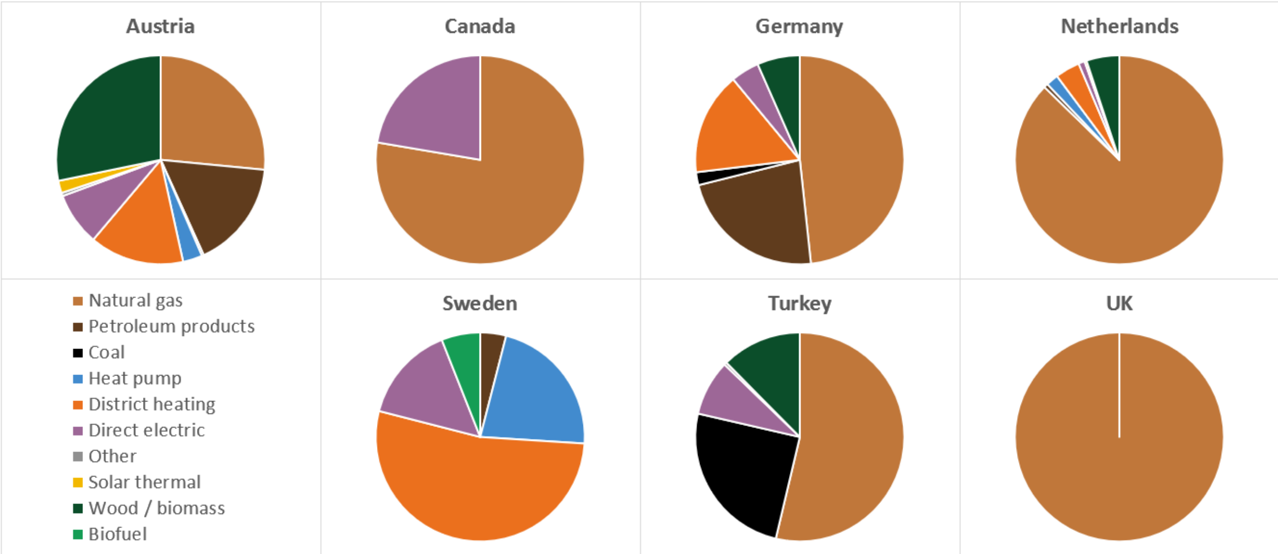

Figure 1 – Energy sources for domestic heating in participating Annex countries (not available for all countries). Note that gas-fired boilers are the dominant heating system in all countries, except for Sweden, where district heating is the largest heating technology.

Austria

- The most common heating system is gas-fired boilers. Heat pumps have a significant share of installed heating systems.
- Natural gas, district heating and wood are used for all household in heating.
- Under the Austrian government's decarbonization policy, the building sector is responsible for 16% of CO_2-emissions. This means replacing the heating systems in 600.000 oil-based houses. Most of these houses will be an opportunity for a heat pump as they are located in rural areas without opportunities for district heating.

Canada

- The majority of Canadian homes use systems that directly heat air via a furnace, heat pump indoor unit, or electric resistance elements.
- Natural gas or propane – 64%
- Electrical heating systems (including both heat pump and electric resistance heating) – 18%.

Germany

- Natural gas is the dominant energy source. Electricity (including heat pumps) with 4.4% is still very low in total consideration. In new buildings, heat pumps have the biggest market share.

Sweden

- District heating, heat pumps, electrical heating and biofuel boilers are the main heating systems used.

- District heating covers more than half of the total heating demand to housing and premises, heat pumps and electrical heaters together have one-third share.
- District heating is mainly used for multi-family houses and premises, HP is dominant in for single-family houses.

Turkey

- For heating in residential sector natural gas is the dominant (53.7%) energy source, followed by coal (24.9%), wood (12.4%) and electricity (8.6%) – including heat pumps and resistance heaters.
- For domestic hot water natural gas (51.8%), coal (3.5%), wood (4.0%), electricity (26%), solar heat (11.5%) and others (3.2%).
- A few district heating networks with a total of 135.000 connected houses using geothermal energy.

United Kingdom

- Boiler sales are still dominant, over 85% of the 26 million housing stock have gas central heating.
- In UK (England, Scotland, Wales and Northern Ireland) there are 4 legislative structures. In England (23 million homes), over a third (36%) of water heating systems used central heating. In Scotland, there are 2.48 million homes with typically 82% of these with gas central heating. In Wales, 94% of the 1.432 million houses use central heating of which 82% are gas-fired central heating.
- Under the Future Homes Standard, new build home will not be able to use gas by 2025. Replacing an existing gas boiler in an existing home will be still allowed.

USA

- Heating is still largely provided by non-electric furnaces and boilers, so winter heating does not incur large electrical power demand.
- HP use in southern regions is attractive since it replaces the central air conditioning (AC) unit while also providing heating during winter months.
- Improvement of heating performance and technological properties of early generation of heat pump increased their use for both heating and cooling in all climates.

2.4 Heat pump deployment

Heat pump deployment varies per country depending on climate and maturity of the market.

Austria

- HP systems are very well accepted, especially in new small family houses.
- Increasing market share of air source HPs in new buildings (ca. 75-80 %).
- In 2018, a total of 25888 heat pumps of all categories and performance classes (heating, domestic hot water, residential ventilation and industrial heat pumps) were sold on the domestic market. In relation to previous years, the sales figures increased by 3.0%.
- In the heat pump market for residential heating, the annual sales rose from 2 025 units to 12 645 units between 2000 and 2008, which corresponds to an annual increase of 25.7%. The sales figures for domestic water heat pumps rose from 2 690 to 5 572 in the same period, equivalent to an annual growth of 9.5%.
- The heat pump market is divided into two groups as Residential and Single-Family house markets.
- For residential market total 26.000 units were sold in 2018 (as industry: 105, residential ventilation: 295, heating: 20270 and hot water: 5218)
- For single family house (below 10 Kw) excluding mechanical ventilation, total 15.608 heat pumps were sold in 2018 (exported: 5298, domestic: 10310). The majority of these systems are for combined heating and hot water preparation.
- Passive House Heat Pump Compact Units (PH): A heat pump compact unit combines mechanical ventilation with heat recovery and a small exhaust air heat pump for space heating and domestic water preparation. With these compact units, Passive Houses can be completely supplied with heat and fresh air. In terms of heating or heat pump power, roughly two classes can be distinguished:
- classic PH heat pump compact units with 1.4 to 2 kW
- "large" compact units with 4 up to 22 kW.
- The sales numbers of compact heat pump systems combined with residential comfort ventilation, as typically used in single-family passive houses are 311 units in 2018. PH's growth rate is 57% between 2017 and 2018, although there is no clear trend. PH Market in Austria only eight manufactures provide (PH) certified heat pump compact units.
- Exhaust air heat pumps: Some companies offer so-called exhaust air heat pumps, which work without heat recovery and can therefore be very compact and operated with relatively high COP due to the high source temperatures (remark: exhaust air heat pumps use room air as source and thus should better be called extract air heat pumps).

Canada

- Heat pump market is growing over the last ten years.
- Over 700,000 heat pumps installed are mostly air-to-air units.

Germany

- The heat distributions systems are generally dominated by water-based systems, so mainly air-water source heat pumps are used.
- The German heating devices market is rather a high-price market. Similarly for the heat pump market. Despite the fact that the heat pumps units and at the same time their operation costs are high (due to very high electricity price), the heat pumps market is growing constantly.

China

- GSHP applications reached 210 million m^2 (heated floor area).
- Air source heat pumps have a large market share.

- Air source heat pump dryers and water heaters are merging.

Italy

- 1.3 million heat pumps sold every year; air-air heat pumps (more than 98%) and about 75 % of them are < 7 kW.
- The sales have doubled in the last four years.
- Cooling-only or cooling-prevalent usage
- Sale of air/water type is around 38’000 in 2018.
- Positive trend observed is for hybrid systems.
- GSHP annual sales are below 1000 units.

The Netherlands

- Technical developments lead to quicker and easier installation in typical Dutch houses. e.g.: small-sized HPs, hybrid packages (i.e. HP + boiler), roof-top solutions for outdoor units.
- There is a sharp increase in the number of HPs and hybrid HP systems sold yearly.
- Heat pumps constitute about 10% of the total domestic heating market.
- New houses are no longer gas connected. I.e. they are heated by HPs (mostly) or collective heating.

Sweden

- Over 1,6 million heat pumps are in operation.
- 50% is air-to-air heat pumps producing mainly space heating,
- 50% of the heat pump systems sold during the last 10 years are hot-water systems for radiators or under floor heating including ground source (GSHP), exhaust air (EAHP) or air to water (AWHP) heat pumps producing both space heating and domestic hot water (DHW).

Turkey

- More than 2,2 million heat pumps are sold in 2018.
- Air-air-heat pumps dominate this market.
- Mini-split units that can provide both heating and cooling are widespread all over Turkey.
- The majority of these units are for cooling and heat pumps are not generally used as the building’s main heating source.
- Air-water- heat pumps and ground-source-heat pumps are less common.

United Kingdom

- HP market in the United Kingdom has been developing slowly. As one of the two potentially biggest markets in Europe (along with Germany), the UK sells 0.95 heat pumps per 1000 households.
- More than 26000 heat pumps are sold in 2018.
- Heat pump market is expected to double by 2025.

USA

- Air source heat pumps are a very mature and well-accepted technology that is widely implemented to provide both heating and cooling.
- HPs are sold from Alaska to Florida, and over 40% of all new homes in the U.S. use a heat pump (over 65% of new homes in the south).

2.5 Storage deployment

Austria

- Thermal storage is included in all the existing CCBs.
- In case of Single-Family House type of heat pump systems, research and development efforts are currently focusing on combined systems with other technologies such as storage-, solar thermal- or photovoltaic systems in favor of the development of new energy services such as room cooling and air conditioning. Integration into smart grids complements the range of innovations.
- Political approaches need to be renewed to overcome social-behavioral barriers and skill shortages.
- Technical advances and increased knowledge generation in the fields of non-flammable refrigerants and unified communication protocols are necessary.

China

- Energy storage for “peak shifting and valley filling” of the power grid.
- Energy storage systems have become a hot research topic in the HVAC industry.
- HP and water storage combined use.
- Effective operation control strategy for different systems is very important.

Germany

- All heat pumps covering the domestic hot water needs, individually or in combination with space heating, are equipped with water storage usually with the volume from 150 to 300 L.

The Netherlands

- Limited ‘storage awareness’ has not hampered HP deployment yet, since a large share of the market has been delivered through hybrid HPs, with gas boilers covering the hot water demand. However, if all-electric HPs are to become the standard retrofit option, storage tanks will have to be accepted by house owners. Compact thermal storage and/or electrical batteries are being tested as part of a package unit.

Sweden

- Thermal storages (water tanks, underground thermal energy storage) and batteries are commonly used in CCB projects.
- Almost all heat pumps heating via a hydronic heating system covers the domestic hot water needs, in combination with space heating. They are equipped with water storage usually with the volume from 150 to 300 L.

Turkey

- Water tanks are commonly used for heat storage without heat pump in residential buildings. Some underground thermal energy storages for seasonal purposes are available for larger buildings.
- Strong solar thermal market for domestic hot water use

United Kingdom

- It is forecasted that at 25% of homes will have some sort of thermal storage and therefore under certain scenarios, the CCB concept has potential market growth. Owner occupied homes were more likely to heat their water using the central heating system with a hot water cylinder. Replacement of these tanks with thermal energy storage will lead to approximately 40% potential for thermal energy storage to be deployed in English homes.
- Compact thermal storage is available, e.g. phase change materials.

- For apartments, there are examples of smaller units with integrated water based thermal storage e.g. the 1.5 kW HP which uses Refrigerant R290 delivering a heat demand 4 kW as a new building so under floor heating temperature of 20°C and a domestic hot water temperature of 60°C.

USA

- TES for both heating and cooling are desirable in the U.S. Ice storage is available (especially commercial systems), but hot storage for space heating purposes not widely used for efficiency benefits.
- Thermal storage for HVAC systems has primarily been in the cooling domain.
- The main commercially available option in the U.S. is heat pump hot water (HPHW) heaters. Several U.S. manufacturers offer HPHW systems for efficient production of domestic hot water.

3 CCB-systems on the market

This chapter gives an overview of available CCB systems and ongoing CCB projects. Although the authors cannot guarantee completeness, this chapter still gives a good impression of the most active and promising CCB systems in the participating countries in the Annex.

3.1 Available systems

Austria

- Several CCBs for different kind of buildings are on the market in Austria. Austrian CCB's are able to provide heating/cooling and DHW generation. All of them have thermal storage integrated and some of them include controllers for optimized PV self-consumption and are SG Ready. Some can also be integrated with comfort ventilation systems and some are prepared for solar thermal systems. Only one company has a product combined with Electric Storage integration. Their installations vary from split units to compact units, and SCOPs are between 4.1 and 5.5.
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Canada

- CCBs have the potential to play a key role in supporting Canada's clean energy objectives. In particular, CCBs may assist in Supporting Increased HP Adoption and Increased Renewable Energy Generation (REG).
- Regarding to HP adoption, CCB offers a link between the thermal and electrical networks, with the ability to store thermal energy for use during peak hours.
- Regarding to REG, CCB products provide utilities with the flexibility needed to decouple building heating demand from heat pump operations, which can allow for increased self-consumption rates for small-scale renewable generation and support higher shares of renewable energy in Canadian electricity grids.
- CCB products are limited in the Canadian market. However, some near to market units do have some level of built-in monitoring, these are Air-based and Hydronic distribution systems. In air-based distribution system where is only a single ductless CCB configuration close to availability on the Canadian market, but for Ducted Heat Pumps no CCB systems are currently available in a centrally ducted configuration. Air based distribution system consist of ductless and ducted heat pump. In ductless frame, the unit is available in a single capacity (2 tons, 7 kW), and offers homeowners and utilities a load shifting capability of 2 kW. It also offers the ability to develop custom operational schedules and monitor system operations through a mobile app.
- In Hydronic Distribution Systems: It was not able to identify any systems combining with the full CCB definition. Six systems were found that link a heat pump with thermal storage (provided by the manufacturer or approved third party), which could provide the basis for CCB development. All systems target low to medium temperature hydronic systems, with maximum outlet water temperatures between 55°C and 60°C.

China

- Near to commercialization: GSHP and water storage coupling system can directly supply energy to users or store energy in energy storage water tanks.

Germany

- In the majority of cases in existing buildings the heat pump systems enclose the buffer tank. In new buildings equipped with the underfloor heating systems, the buffer tank is not necessary and therefore usually not installed. In all systems covering also domestic hot water preparation, DHW tank is included. The integration of both tanks can be executed in several technical ways.
- In the passive house application, gained solar heat from irradiation can lead to peak load as 10 W/m2. This combination of air heating and ventilation systems leads to new solutions compared with a conventional heating system based on hot water. This storage tank forms the interface with a solar thermal system. If neither the solar heating unit nor the heat pump provides sufficient heat, supplementary heating of the storage tank is provided by an electrical resistance heating element.
- The use of an underground earth-to-air heat exchanger reduces the heating requirement and raises significantly the temperature of the heat pump´s heat source.

Italy

- Building types with CCB can be grouped according to the following:
  - residential small size systems (3-15 kW)
  - single or double family houses (about 25% of the building stock)
  - air-air and air-water heat pump
- Some of the best practices on the market are:
  - An innovative thermal store in the smallest of spaces with electronic management of both heat pump and thermal store (ISM = Intelligent Store Management) maximizing energy efficiency at the same time as heating and domestic hot water. Smart Grid Ready label for some brands heat pumps certifies their suitability for “power bias operation”.
  - A hydronic group allowing to combine condensing boiler for heating only, heat pumps and solar thermal to heat, cool and produce hot water.
  - Air source heat pump working in combination with a hydraulic tower (which contains all the necessary hydraulic components for the installation of the heat pump as well as a 190-liters hot water tank.) to provide cost-effective comprehensive comfort. Its modulating compressor automatically adjusts output to the current building heating load.
  - A unit designed for SH, SC and DHW and is ready for integration with solar thermal or external boilers.

The Netherlands

- At least 10 ‘CCB’ manufacturers on the market in the Netherlands.
- The first ones on the market have two different types of CCB´s, one to install under and in the roof, the other one to install in front or at the back of the house.
- Different heat pump companies presented new CCB´s. All the CCB’s combine a ventilation unit with heat regeneration, an air/water heat pump, a small buffer-tank for heating and a larger buffer-tank for (hot) tap water. Also, CCB’s combine water/water hp in combination with buffer-tank (and PVT). the focus is on compactness, efficiency and smart-ready.

Sweden

- There are many heat pump systems already on the market or close to commercialization that includes one or several functions related to CCB:
  - HPs and power consumption: Smart price adaptation/smart grid ready, Maximal power consumption, remote control and monitoring, Cloud based and ITTT (If-This-Than-That), Self-learning
  - HPs and PV

- HP and solar thermal: GSHP in combination with a solar collector and DHW tank (varying in size, normally of 500 l), HYSS (Hybrid Solar System) combining conventional HP with solar thermal production and storage (tank and boreholes) in three different ways.
- HPs for cooling: Active cooling by using cold side of the HP, passive cooling with GSHP.

- Heat pumps for space heating and DHW with high efficiency, standardized size (60*60*200 cm) and easy to install are commonly used in single family houses.

Turkey

- CCB market is very new in Turkey. No mature data is available on projects except for the CCB use cases.
- Nearly all of these systems are composed of imported components. These systems commonly use PV as renewable power source and floor heating. The HPs are air-water or ground source. Water tanks and Li-ion batteries are used as storage media. The control systems optimize the system operation based on the demand for heating, cooling and hot water of the building.

United Kingdom

- Some examples of air source heat pumps with appropriately sized associated thermal storage units by different brands are available on the market.

USA

- There are different ways to consider the CCB:
  - For a system design with the most desirable features (typical European perspective) with a heat pump primarily used for heating and incorporating storage for both HW and space heating efficiency
  - For a heating and cooling system that includes ice storage, for the US market.
  - The ORNL perspective (system with PCM TES) is very different still.

3.2 Field trials and best practices

The projects in participating countries that are suitable to the central concept of CCB consisting of heat pump, energy storage and controls are given in Table 4.

Table 3 – CCB project from participating countries (C: Completed, O: Ongoing, P: Planned).

Country	Project Description	Heat Pumps	Storage	Year	Status
Austria	**HYBUILD –** *In the Continental HYBUILD-concept, the sensible heat of the hot superheated refrigerant after the compressor of an R32-air-source HP is used to store thermal energy in a latent storage at a high temperature level suitable for DHW generation.*	A-W	PCM	2017-2022	O
Austria	**CoolDiffusion –** *In CoolDiffusion, market- and policy-based diffusion strategies for innovative cooling systems in multi-story residential buildings are analyzed and developed. Methods developed in CoolDiffusion, can also be used to analyze the diffusion of CCBs into the market.*	All types	All types	2019-2021	O
Austria	**PH Compact HP –** *Passive House Compact Heat Pump with Mechanical Ventilation with Heat Recovery; Lab Measurements, Simulation, Energy Balance on Building Level, Monitoring.*	Exhaust-Air-to-Supply Air	Water	2020-2021	O
Austria	**FiTNeS –** *In the FFG project FitNeS different concepts for façade-integrated outdoor units for air to water heat pumps are developed and evaluated with regard to design, façade construction, accessibility (for maintenance), building physics, efficiency, etc.*	A-W	Water	2019-2022	O
Austria	**HybridHeat4San –** *In HybridHeat4San an innovative combination of air-to-water heat pump, photovoltaic system, thermal storage and intelligent control is developed, which allows heat supply of thermally renovated residential buildings with high efficiency.*	A-W	Water	2017 - 2021	O
China	**Phase change energy storage integrated heating and cooling system in Beijing –** *The system consists of an air source heat pump, capillary network and energy storage unit in the floor.*	A-A	PCM	2019-2022	O
China	**GSHP energy storage system for near-zero energy demonstration for office building in Beijing –** *The system uses solar heat in combination with thermal storage for heating, GSHP for heating and cooling, absorption chiller and magnetic suspension chiller with cold storage for cooling.*	GSHP	Cold & Heat	2013-2017	C
Germany	**100 Passive Houses with Heat Pumps Compact Units in several locations of Baden- Wuerttemberg –** *The project compared efficiencies of two different heat pump systems in 50 passive houses:* • *ground heat pump with water-based heat distribution system (primary underfloor heating).* • *compact ventilation unit with an integrated heat pump, in which the heat pump resumes the task of space heating (with the heat distribution through air) and of domestic hot water.*	GSHP & A-A	Water	2000-2004	C

Country	Project Description	Heat Pumps	Stor-age	Year	Status
	Heat pumps field tests (several titles) at 250 different locations across Germany – *air-to-water and brine-to-water heat pump systems have been investigated under real operating conditions in houses with various energetic standards (from low-energy to un-retrofitted stock buildings with high energy demand.*	GSHP & A-W	NA	2006-2019	C
Netherlands	**The Helena Concept –** *New concept to combine 5 – 10 houses in a 'micro' heating grid, with a single GSHP. This enables the use of expensive GSHP systems for houses with a relatively low heating demand.*	GSHP	Water, BTES, Bat-teries	2019 -	O
	Future Factory – to *develop a compact a/w heat pump concept without outdoor unit in several typical homes. (Heat pump/PV/storage tank combination).*	ASHP		2019	O
	High impact installations – to *develop a compact w/w heat pump concept in several typical homes. (Heat pump/PVT/storage tank combination)*	GSHP	Water, BTES	2020	O
	IEBB Compact Heat storage systems – *to develop different kinds of compact heat storage systems: PCM, TCM, redox (different TRL's)*	-	PCM, TCM, TCS, Redox	2019	O
	All-in-one concepts – *pre-fabrication of compact all-in-one units for several typical houses) consortia renovation& installation market.*	All		2019	O
Sweden	**Flexible Heat and Power –** *secure mitigation of RES curtailment in the electric distribution grid by dynamic coalitions of power-to-heat resources.*	All types	NA	2016-2019	C
	Grid flexible heat pump – *estimate the potential for demand response based on coalitions of heat pumps in apartment buildings.*	All types	NA	2017-2018	C
	Test of solar heat pump systems- TESHP – how *the control of systems with PV and heat pump can be optimized and tested in the lab so that the operational functionality can be verified, and performance determined in a quick and efficient manner using the so called accelerated quasi-field testing of the whole system.*	Exhaust air	Water, Bat-teries	2017-2020	O
	Probabilistic Forecasting for Battery Management – *analyze how a probabilistic forecast of PV generation and a machine learning algorithm can be used to enhance the battery dispatch for a single-family household with the objective to maximize the economical profit.*	GSHP	Bat-teries	2019-2020	O
	From photovoltaic generation to end-users with minimum losses – a full-scale demonstration – *performance of a PV and battery system with regards to its grid interaction, self-consumption of PV and energy efficiency gains of a low-voltage direct-current (LVDC) distribution system including prototypes of a ground-source heat pump and ventilation system.*	GSHP	Bat-teries	2017-2020	O

Country	Project Description	Heat Pumps	Storage	Year	Status
	IRIS – Smart Cities – *recommendations capable of allowing a smarter and more efficient grid balancing, not only as concerns the electricity, but also additional energy streams distribution as those of heating/cooling on a city level basis. Including the interaction between heat pump(s) and district heating in the two user-cases – Campus Johanneberg and Medical campus in Gothenburg.*	All types	Thermal & electrical	2017-2022	O
	Optimization of combined solar hybrid and geothermal systems – *control parameters affect the energy efficiency of these systems and studying different borehole configurations and how these affect the possibility for seasonal heat storage, including PVT.*	GSHP	BTES, water	2016-2017	C
	FED – Fossil-free Energy Districts – grid-*connected local energy system with demand and supply in balance, integrating electricity, heating and cooling with PVs, HPs and wind, thermal and electrical storage, and a local energy market and trading system functioning in symbiosis with the existing energy market.*	GSHP	Thermal & electrical	2016-2019	C
	EnergyMatching – *maximize the RES harvesting in the built environment by developing and demonstrating cost-effective active building skin solutions as part of an optimized building energy system, being connected into local energy grid and managed by a district energy hub implementing optimized control strategies.*	All types	Water and Batteries	2017-2022	O
	MacSheep – New Materials and Control for a next generation of compact combined Solar and heat pump systems with boosted energetic and exergetic performance – develop *new innovative products and advanced test methods for a next generation of compact combined renewable energy systems based on solar thermal and heat pump technology for space heating and hot water preparation, using breakthroughs in ICT, new materials and technology.*	All types	Water	2012-2015	C
	Further development of heat pump systems for Nearly Zero Energy Buildings – *develop new knowledge on heat pump design and the operation and installation for a NZEB for space heating, ventilation, DHW, passive cooling.*	All types	Water	2015-2018	C
Turkey	**Yozgat project –** *Optimizing self consumption of a single-family house energy system based on renewable electricity with PV, Li-ion battery storage, heat pump, water storage + combi – for space heating with under-floor heating and DHW with smart control.*	A-W	Water and Li-ion batteries	2019-	O
	Ankara Project – *Optimizing self consumption of a single-family house energy system based on renewable electricity with PV, Li-ion battery storage, ground source heat pump using horizontal ground loop, water storage + combi – for space heating and DHW, free cooling from ground loop in summer, with smart control.*	GSHP & A-W	Water and Li-ion batteries	2019-	O
UK	**Smart Energy Islands, Isles of Scilly –** *including batteries and air source heat pumps, Internet of Things (IoT) platform and*	A-A	Batteries	2018-2020	P

Country	Project Description	Heat Pumps	Stor-age	Year	Status
	Artificial Intelligence (AI), to reduce the carbon footprint of the island whilst optimizing locally produced, renewable energy.				
	Greater Manchester Smart Energy Trial – *a large scale field trial, replacing old inefficient heating systems in 550 social housing, electrical and hybrid air-source heat pumps and developing an energy aggregation system and ICT platform to control and coordinate the electricity usage and testing the effectiveness of this reduction.*	Hybrid A-A	NA	2014-2016	C

4 Quality criteria and implementation strategies

Part I of the Annex report series discusses the CCB implementation strategy and their corresponding quality criteria. This chapter presents an overview of these criteria as applied to the CCB markets *as a whole*. All based on expert judgment from the participating country representatives. In that sense, the judgements may be subjective, but they should be consistent within any given country and give at least a good starting point for a country comparison.

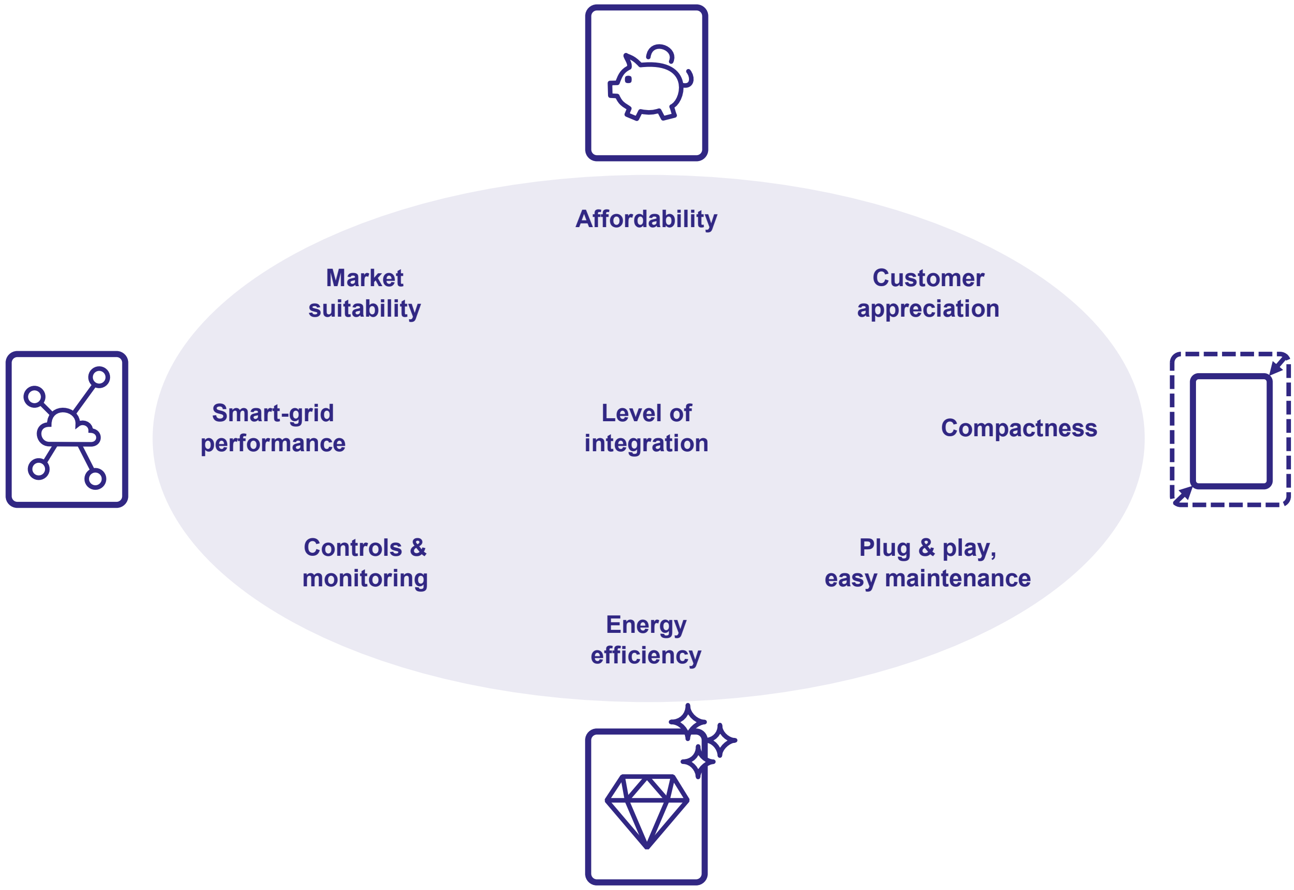

Figure 2 – Implementation strategies and associated quality criteria.

4.1 Assessment per country

The diagrams below (Figure 3) give the assessment of all quality criteria. The judgement is split into two sets of scoring digits/colors:

- Priority: how important is the criterion in the local market?
- Current: how well has the criterion been satisfied by the locally available systems already?

The scoring is as follows:

Priority		Current	
1	very important	1	more or less solved
2	important, not top priority	2	not yet solved, but progress
3	relevant issue, no priority	3	just starting to get attention
4	not an issue	4	not yet addressed

Austria	Priority	Current
Affordability	2	2
Market suitability	1	2
Smart-grid performance	3	3
Controls & monitoring	1	2
Energy efficiency	1	2
Plug & play, easy maintenance	1	2
Compactness	2	2
Customer appreciation	2	2
Level of integration	1	3

Canada	Priority	Current
Affordability	1	3
Market suitability	1	4
Smart-grid performance	1	4
Controls & monitoring	2	3
Energy efficiency	2	3
Plug & play, easy maintenance	2	3
Compactness	2	3
Customer appreciation	2	3
Level of integration	2	3

China	Priority	Current
Affordability	1	2
Market suitability	1	1
Smart-grid performance	3	1
Controls & monitoring	1	2
Energy efficiency	1	3
Plug & play, easy maintenance	2	3
Compactness	2	3
Customer appreciation	2	3
Level of integration	3	2

Germany	Priority	Current
Affordability	2	2
Market suitability	1	2
Smart-grid performance	3	2
Controls & monitoring	2	2
Energy efficiency	2	1
Plug & play, easy maintenance	2	3
Compactness	3	3
Customer appreciation	2	3
Level of integration	3	3

Figure 3 – Assessment of quality criteria for each the CCB market participant country.

Italy	Priority	Current
Affordability	1	3
Market suitability	2	1
Smart-grid performance	2	3
Controls & monitoring	1	3
Energy efficiency	1	2
Plug & play, easy maintenance	3	4
Compactness	2	3
Customer appreciation	2	4
Level of integration	2	3

Netherlands	Priority	Current
Affordability	2	2
Market suitability	1	3
Smart-grid performance	3	3
Controls & monitoring	1	3
Energy efficiency	2	1
Plug & play, easy maintenance	1	2
Compactness	2	3
Customer appreciation	2	3
Level of integration	3	3

Sweden	Priority	Current
Affordability		3
Market suitability		3
Smart-grid performance		4
Controls & monitoring		2
Energy efficiency		2
Plug & play, easy maintenance		2
Compactness		3
Customer appreciation		2
Level of integration		4

Turkey	Priority	Current
Affordability	1	3
Market suitability	1	2
Smart-grid performance	1	3
Controls & monitoring	1	2
Energy efficiency	1	1
Plug & play, easy maintenance	1	2
Compactness	1	2
Customer appreciation	1	2
Level of integration	1	3

UK	Priority	Current
Affordability		3
Market suitability		4
Smart-grid performance		4
Controls & monitoring		3
Energy efficiency		2
Plug & play, easy maintenance		3
Compactness		3
Customer appreciation		3
Level of integration		2

USA	Priority	Current
Affordability	1	3
Market suitability	1	2
Smart-grid performance	3	3
Controls & monitoring	2	3
Energy efficiency	2	2
Plug & play, easy maintenance	2	2
Compactness	3	2
Customer appreciation	1	3
Level of integration	3	4

Figure 3 (cont.) – Assessment of quality criteria for each the CCB market participant country.

The following paragraphs detail the assessments for each criterion and each country.

Affordability

- Austria: HPs and storages are more expensive than gas boilers in spite of the existing subsidies, HP operation is competitive because of low electricity price.
- Canada: Investment, operational, and any maintenance costs have priority. First cost is important.
- China: GSHP combined water storage system can save about 7% of the initial investment.
- Italy: Low capital cost investments are addressed in the market, despite their running costs could be higher than other solutions. Electricity vs gas costs are not in favor of HPs. Fiscal incentives are needed.
- The Netherlands: Investments are relatively expensive in comparison with condensing boilers. The sheer size of the investment can be prohibitive. Running costs are set to become much better compared to condensing boilers.
- Sweden: For HPs, the investment cost is considerable, but the running cost is lower due to relatively low electricity prices. Adding energy storage increases the payback time.
- Turkey: It is very important to have affordable systems to widen use. Major components of CCB are mostly imported and current taxes used for imported goods make them even more expensive. For CCB incentives or other financial back-ups may be helpful.
- UK: air source heat pump, and a water thermal storage with hot water is more expensive, but there is a subsidy. “Mis-application” cases where wrong type of heat pump is installed can lead to high energy cost.
- USA: Cost depends very much on specific system/configuration being considered. CCB can incorporate many different features. In general, this goes hand in hand with customers understanding the benefits and savings potential to be able to valorize added costs for a more complex system. This may depend on location since TOU pricing will change the economic value for different systems.

Market suitability

- Austria: High flow temperatures are required, limiting efficiency of the HP.
- Canada: It should easily integrate into Canadian buildings without requiring major changes to HVAC systems.
- China: The type of building with a lighter load or a heavy load during the trough period of electricity at night is not suitable for GSHP coupling system in terms of residential.
- Italy: Currently there is a good matching between the market demands and the suitability of available HP models. There are many available sizes and costs to fit all the customer requests.
- The Netherlands: Present market systems tend to be too large (high power), and not designed specifically for NL houses.
- Sweden: Sweden: HP exists within a large capacity range. HP and energy storages with varying sizes exist, but incentives and control system to combine them are rarer. Solutions for distributing (free) cooling from the heat pump to the whole house are not very common.
- Turkey: The large number of HP systems are air-air used mainly for cooling; ground source is limited. HP is the only solution used in the houses for cooling, For CCB AAHPs are readily adaptable, but AWHPs and ground source HPs still need improvements.
- UK: Higher levels of complexity of some systems have made it difficult for the end-user to understand whether the system is operating as efficiently as it should.
- USA: Generally good for existing commercial systems, but other functionality for an ideal system still needs to be further developed and commercialized. For example, PCM storage for both heating and cooling.

Smart-grid performance

- Austria: Energy provider does not support the technology nationwide.
- Canada: High importance without adequate smart grid capabilities, the business case for CCB adoption would be limited.
- Italy: Some manufacturers already state the compatibility with the SG. Their devices are declared to be able to give priority autonomously to the cheapest electricity source and to store heat preventively to face the most expensive hours. However, the energy market in Italy is not yet mature to support demand response initiatives, and the SG-ready systems are at an embryonic development state.
- The Netherlands: Manufacturers claim 'SG-ready', but in practice not much is done.
- Sweden: Seldom applied today. One reason for this is the relatively small variations in electricity price today and small difference between feed in and feed out tariffs for onsite produced electricity.
- Turkey: Smart grids are not currently very important for HPs. Use of CCB in smart grids may have additional benefits. Existing CCBs are smart grid ready, but not in use. There are no smart grid standards available.
- UK: Manufacturers claim 'SG-ready' and there have been a number of field trials.

Controls & monitoring

- Austria: Controls could be improved. Automatic commissioning and optimization would improve system performance; fault detection and self-acting KPI-reports are required.
- Canada: Provide useful data on current system operations and offer feedback to installers in order to optimize system integration.
- China: It is still in the non-standardization stage
- Italy: Many control & monitoring interfaces are already available. Controls are generally at a basic and user-friendly level. It is not practice to tune the control system to the specific conditions of the real installation. Sometimes, the system may be managed through a smartphone App. However, security against digital attack is not felt as a critical issue at the moment, but it should be addressed.
- The Netherlands: Monitoring is still not standard, cyber security is important.
- Sweden: Still very few heat pumps on the market are operated with an integrated control of the solar PV or monitored.
- Turkey: It should be easily controlled with possibility to have remote control. Monitoring is not common practice for HPs. Defrosting may be a problem in HPs in very cold climates. Existing CCBs have advanced control units and monitoring of several parameters and performance can be done. Advanced control systems increase the cost of CCBs, simpler and more cost-effective control systems are needed.
- UK: Electric heat pumps feature prominently in projected energy transitions, owing to their high electricity consumption, heat pumps are viewed as important targets for demand-side response.
- USA: There is some specific know-how developed, but there is a long way to go for highly optimized control, especially for general case.

Energy efficiency

- Austria: High temperature could be a problem. Commissioning and control optimization / fault detection are important.
- Canada: A significant focus of development needed for cold climate heat pumps.
- China: Coupled with DSHP can lead COP 4.3

- Italy: The efficiency is one of the most important goals, being directly linked to the main CCB objectives. HP efficiency is generally good, but it may be improved, in particular with cold and humid climate conditions.
- The Netherlands: Efficiency of HPs is not yet as high as it could be.
- Sweden: The efficiency of the separate functions is good enough.
- Turkey: For cooling dominant climates in Turkey, higher outside temperatures decreases the COP in summertime. The efficiency of current CCBs deliver the expected performance. CCB are much more efficient than HPs.
- UK: Efficiency of an air-source heat pump is highly dependent on heat emitter type and sizing. Reducing heat loss of buildings and upgrading radiators will improve the efficiency of the operating heat pump by lower heat delivery temperature for space heating.
- USA: Technology has a lot of promise/has inherent efficiency potential but see comments under controls. Could rate as 3 depending on interpretation.

Plug & play, easy maintenance

- Austria: Interfaces should be standardized; using different manufacturers could be problem.
- Canada: Require more knowledge and training for installers, and ultimately slow market adoption.
- China: Still work to do to improve the level of operation and maintenance personnel.
- Italy: The installing process is rather far from being an easy job, especially in retrofitting, due to not standard hydraulic connections. Maintenance network not yet widespread enough.
- The Netherlands: Lack of skilled installers. Incentives are needed.
- Sweden: For HPs combined with energy storage plug-play maintenance is rare.
- Turkey: HPs are delivered with necessary controls and maintenance is easy. More advanced control systems for HPs are not there yet. Existing CCBs require technical experts to provide proper functioning of all the components. Each component may have different maintenance requirements.
- UK: Sizing and installation and maintenance need a service provider with greater skills than are typically available. There are only some experiences with thermal storage. There are difficulties associated with maintenance due to the low number of companies able to maintain a heat pump compared with a more traditional heating system.

Compactness

- Austria: Size should be minimized.
- Canada: Large space requirements for a system can limit adoption. Homeowners and builders often wish to maximize the livable space within a building in case such that sizing cannot be problem.
- China: Increase in volume of energy storage will increase the heat loss of the system.
- Italy: HP systems are currently not compact enough, especially when air-source units are used. Compact storages are not yet widely available. Regarding the selected target houses, the compactness is important.
- The Netherlands: Compactness is very important, given the relatively small houses in the Netherlands. Roof-mounted monobloc systems may be feasible, but market does not take off yet. In existing houses, hybrid systems are mainly used, because they do not need a storage tank for DHW.
- Sweden: Adding on extra energy storage might add on indoor footprint.
- Turkey: Existing buildings may have available space, but limited space in new houses can be challenging. CCBs with improved and smaller volume storage designs are needed.

- UK: Traditional homes have enough area for DHW storage of about 200 liters, but in the new ones with gas-fired combi boilers that has removed this option. The value of the space in inner city housing coupled with a home improvement drive.
- USA: This is not a big issue in U.S.

Customer appreciation

- Austria: HP systems are very well accepted, sound issues, a combination of modulating heat pumps with photovoltaics is not common.
- Canada: Stakeholder appreciation is a critical issue.
- China: The social recognition is important.
- Italy: The main limiting reasons are the high costs and the space constraints. Target customers are not aware of HPs and storage options. HPs are still considered as 'something complicated' that customers have to deal with. The aesthetic impact may be a limitation too, especially when installed in locations subject to landscape restrictions.
- The Netherlands: Acceptance must still grow.
- Sweden: As long as the life cycle cost for the new product is not higher than for existing heat pump solutions, the potential for high appreciation is good.
- Turkey: Very important for the user to be happy with the system. HPs are widely accepted for cooling purposes, but natural gas systems are preferred for heating. The limited number of existing CCBs are highly appreciated by users, but the market is still developing. Demonstration projects showing multiple benefits and self consumption opportunities are needed.
- USA: I take this to mean public acceptance and awareness of the technology and its benefits. Most people from general public have no idea of benefits of storage.

Level of integration

- Austria: In case of different manufacturers integral design should be done in a correct way (HP and ventilation system), sound problem.
- Canada: Appropriately integrated system helps to maximize performance and avoid potential issues related to equipment compatibility.
- Italy: Integration plays a key role since a fully integrated product may promote a better spread on the market. The storage is generally suitable for many sizes and solutions.
- Netherlands: Within the 'zero energy houses' movement, the tendency is to design integral units, containing heating, hot water, storage and ventilation. These units are typically placed in a dedicated 'add-on' box outside of the house. This concept is very successful in projects involving dozens of houses at a time. It can be expected to be developed further for use in individual houses as well.
- Sweden: Except for the integration to the DHW tank, heat pumps are seldom integrated with any energy storage, or with an integrated control of the heat pump combined with the storage.
- Turkey: HPs are available as packed units for residential use. CCBs should be adjusted to the building design at an early stage for better results.
- UK: There is an increasing amount of experience with an integral design approach to air source heat pumps associated with the use of the Microgeneration Certification Scheme (MCS). Standard addresses only domestic hot water (DHW) storage and not thermal storage for demand side management/response.

4.2 Combined assessment

Based on the country input, we have compiled a sorted overview of the priority assessment and the current status assessment. The assessment has been applied to the CCB market in the participating countries (i.e. available CCB systems in relation to policies, building stock, regulations, business case and customer base).

Figure 4 and Figure 5 show the results, with the color code as specified below.

Priority		Current	
1	very important	1	more or less solved
2	important, not top priority	2	not yet solved, but progress
3	relevant issue, no priority	3	just starting to get attention
4	not an issue	4	not yet addressed

Assessment of quality criteria – *Priority areas in local markets*

Affordability	Canada	China	Italy	Turkey	USA	Austria	Germany	Netherl.	Sweden	USA
Market suitability	Austria	Canada	China	Germany	Netherl.	Turkey	USA	Italy	Sweden	UK
Smart-grid performance	Canada	Turkey	Italy	Austria	China	Germany	Netherl.	Turkey	USA	Sweden
Controls & monitoring	Austria	China	Italy	Netherl.	Turkey	Canada	Germany	Sweden	USA	UK
Energy efficiency	Austria	China	Italy	Turkey	Canada	Germany	Netherl.	Sweden	UK	USA
Plug & play, easy maintenance	Austria	Netherl.	Turkey	Canada	China	Germany	Sweden	USA	Italy	UK
Compactness	Turkey	Austria	Canada	China	Italy	Netherl.	Germany	Sweden	UK	USA
Customer appreciation	Turkey	USA	Austria	Canada	China	Germany	Italy	Netherl.	Sweden	UK
Level of integration	Austria	Turkey	Canada	Italy	UK	China	Germany	Netherl.	USA	Sweden

Figure 4 – Priority of quality criteria in local markets.

Assessment of quality criteria – *Present status of local markets*

Affordability	Austria	China	Germany	Netherl.	Canada	Italy	Sweden	Turkey	UK	USA
Market suitability	China	Italy	Austria	Germany	Turkey	USA	Netherl.	Sweden	Canada	UK
Smart-grid performance	China	Germany	Austria	Germany	Italy	Netherl.	Turkey	USA	Canada	UK
Controls & monitoring	Austria	China	Germany	Sweden	Turkey	Canada	Italy	Netherl.	UK	USA
Energy efficiency	Germany	Netherl.	Turkey	Austria	Italy	Sweden	UK	USA	Canada	China
Plug & play, easy maintenance	Austria	Netherl.	Sweden	Turkey	USA	Canada	China	Germany	UK	Italy
Compactness	Austria	Turkey	USA	Canada	China	Germany	Italy	Netherl.	Sweden	UK
Customer appreciation	Austria	Sweden	Turkey	Canada	China	Germany	Netherl.	UK	USA	Italy
Level of integration	China	UK	Austria	Canada	Germany	Italy	Netherl.	Turkey	Sweden	USA

Figure 5 – Status of local markets. I.e. 'how much is there to be done'?

It is interesting to note that market suitability is consistently scored high on the prioritization list, while it scores relatively low on the present status assessment. This is clearly an area that needs to be worked on.

Further areas of importance are smart-grid performance, customer appreciation and system integration. As a corollary to the latter criterion, the CCB markets would benefit from more 'plug & play' ready market offerings, as these make for more affordable and reliable installations.

Finally, it should be noted that while energy efficiency is clearly important, it can also be essentially considered as a 'solved problem' for most countries, apart from Canada and China.

5 Conclusions

This report gives an overview of systems presently on the market or close to commercialization, case histories from already existing CCB concepts or products for the Annex 34/55 countries. Functional conditions and requirements for further improvement of CCBs for the local market are recommended based on the collected data.

There are several factors that influence the current status of market in the countries such as maturity of heat pump market, political drivers, building stock and climate. Different types of heat pumps are already on the market in all the participating countries. The presence of local heat pump producers and promoting technology awareness increase market penetration of HPs and CCBs. Political drivers can help to boost the market, in particular if policy goals are backed by subsidies or even obligations for house owners or building constructors. General conclusions on house types and optimal CCB choices are hard to reach, since housing types differ between countries, but also within countries between urban and sub-urban areas. In cooling-dominant climates air-air heat pumps find more applications. In colder climates water source and ground-coupled heat pumps are seen more.

However, as a general conclusion it is evident that the importance of different CCB aspects (the quality criteria) is rated very differently in the participating countries. At the same time, the assessment of progress that has already been made in satisfying the most important criteria *also* differs strongly between countries. Together, this implies that it will pay off to define *locally specific* research and support goals for CCB technologies, to facilitate the necessary market development. In particular, energy efficiency does not seem to be the most important quality criterion in most countries, while (local!) market suitability, smart-grid integration, customer appreciation and a better integration of storage and HP components generally need more attention.

There are some differences in energy storage concepts or perception. The purpose of using thermal storage with heat pumps is usually considered to be an accumulator or back up tank. The role of thermal storage for closing the gap between supply and demand of renewables or other flexibility options is structurally overlooked and/or underused. Cold thermal storage that makes use of the multiple electrical tariffs seen mostly in North America and South-east Asia are not included in the scope of CCB the current Annex but will likely be included in a future Annex for Comfort and Climate box solutions for warm and humid climates. Thermal storage in Phase Change Materials (PCMs) can fit very well to CCB concept, mainly because of compactness that could be achieved. Batteries (mostly Li-ion) are used in some of the CCB systems with PVs.

The major barriers to CCB that are seen in the participating countries are low cost for gas and boilers, fluctuating gas prices, rising electricity prices, noise level, regional variation of carbon content in grid, high cost of imported heat pumps affected by fluctuating currency rates**.** Variations in electricity prices are too small to motivate the cost of adding thermal storage.

Some of the main opportunities that can be seen in some of the participating countries are policy drivers, increasing awareness of fossil fuel risks, increased pressure on the government to sharply decrease natural gas-dependency, technical developments enabling quicker and easier installation, transformation from large to small power plants, transition to renewable power generation, large differences between peak and valley in power grids, R&D support provided for heat pumps and energy storage, strong solar thermal market for domestic hot water use. Flexibility that can be brought by heat pumps should also be taken in account in evaluating the most economic option.

It is seen that usage of HP and water storage is available in all the participating countries' markets. Interest in different combinations of PVs-batteries-thermal storage-HPs as in CCB concept to maximize renewable integration is increasing, but is not common practice, yet. Further developments for flexibility and compactness can be achieved with PV and PCM combined solutions. Integrated design and control are main features needed for flexibility to the power grid. Today´s heat pumps may need further development related to the design parameters for integrated design and control. Cyber security is becoming important with advanced control systems.

Most heat pumps are claimed to be manufactured smart grid ready, but it is not practiced and there are no standardized applications, yet.

Demand for space cooling is increasing even in cold climate countries. Heat pumps coupled to ground can offer passive cooling via the boreholes or active cooling by using the cool side of the heat pump cycle. For warm climate countries, more efficient cooling with heat pumps at high outside temperatures can be achieved by ground coupling as well. Further development for integrated design and simple installation for such cooling purposes is needed.

A. Related activities

A.1 Related IEA activities

The IEA related activities to this can be found under International Energy Agency Technology Collaboration Programs (IEA TCPs). There are eight Buildings-related TCPs, coordinated through the IEA Buildings Coordination Group. The recent activities (Annexes/Tasks/Projects) in these TCPs are:

IEA Heat Pumping Technologies TCP

Ongoing:

- Annex 57: Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks

Recently completed:

- Task 51: Acoustic emissions of heat pumps
- Task 49: Design and integration of heat pumps for nZEB
- Task 46: Domestic hot water heat pump
- Task 45: Hybrid heat pumps
- Task 41: Cold climate heat pumps

Energy Storage TCP

Ongoing:

- Annex 35: Flexible sector coupling

Energy in Buildings and Communities TCP

Ongoing:

- No 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
- No67: Energy Flexible Buildings

A.2 EU-funded projects

The EU-funded projects recently completed or ongoing that participating countries or taking part in are given in the table below:

Project	Time	Relevance to Task 55/Annex 34	Countries	Link
IRIS	2017-2022	Recommendations capable of allowing a smarter and more efficient grid balancing, not only as concerns the electricity, but also additional energy streams distribution as those of heating/cooling on a city level basis. Including the interaction between heat pump(s) and district heating	SE, NL	https://irissmartcities.eu
Energy-Matching	2017-2022	Maximize the RES harvesting in the built environment by developing and demonstrating cost-effective active building skin solutions as part of an optimized building. energy system, being connected into local energy grid and managed by a district energy hub implementing optimized control strategies	DE, IT, NL, SE	https://www.energymatching.eu
HYBUILD	2017-2022		AT, DE, IT	http://hybuild.eu

Table 4 – EU-funded projects relevant to this Annex.

B. Publications and reports

Recent publications and reports from participating countries:

- Miara, M., Günthera, D., Langnera, R., 2020, Heat pumps in existing residential buildings, 13th IEA Heat Pump Conference May 11-14, 2020, Jeju, Korea
- Patterson, A., 2019, British Standard Institution (BSI), Electrical energy storage Global standards landscape, London.
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