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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 6

Standards

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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.

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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 ES Task 34 and HPT Annex 55

Part VI – Standards

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1 Introduction

The Comfort Climate Box (CCB) is defined within the scope of this Annex as "an integrated system consisting of a heat pump and a storage together with an optimized control". The ultimate goal of the Annex is to speed up the development of CCBs and to bring CCBs closer to the consumer market, focusing on the optimal integration of the CCB components, that can reach their best performance when optimized together for specific tasks.
Given that the CCB is an assembly of components/systems with different features, it is here critically evaluated how it is possible to assess the CCB performance taking all the aspects into consideration and it is analysed if existing standards can cover the integration of components in the CCB.
The term standard is generally used to refer to a measurement method or it can have the meaning of (minimum) requirement. In both cases, standards are very important for CCBs because they can help to measure the performance of these complex systems and to compare CCBs from different manufacturers or with different specifications. Rating a CCB on the basis of its efficiency or flexibility is not a trivial issue, but it is a paramount step for transparency towards the final user and/or the external electricity grid. The purpose of this analysis is to identify potential limitations in the present state of affair and discuss possible approaches to overcome them.
In this report, firstly some preliminary notions will be provided on the main characteristics that depict a standard, explaining how they are related to the CCB. Secondly the state of the art on existing standards referred to the different elements of a CCB is presented for the following areas: Europe, Canada, US, China. An overview of the main findings is reported below. On the basis of the existing standards and of the relevant characteristics of a CCB, the gaps in the existing standards are highlighted and suggestions are provided.

2 Main elements of Standards testing methods

Measurement or test methods (in standards) are used to assess quantitatively parameters of a product, i.e. to assign values to metrics that represent the relevant parameters. These tests are performed in a certain environment, e.g. in a lab, under certain, specified conditions (environmental conditions) and with a certain, specified use of the product (load conditions). The results of the assessment are used for instance for product development or product declaration by a manufacturer or market surveillance by authorities (i.e. the "Testing Purpose" in Figure 1).
Criteria to assess a test method are costs, repeatability and reproducibility, and representativeness.
Applying this framework to the CCB, the elements for the CCB test method are represented in Figure 1 and they are described in detail below.

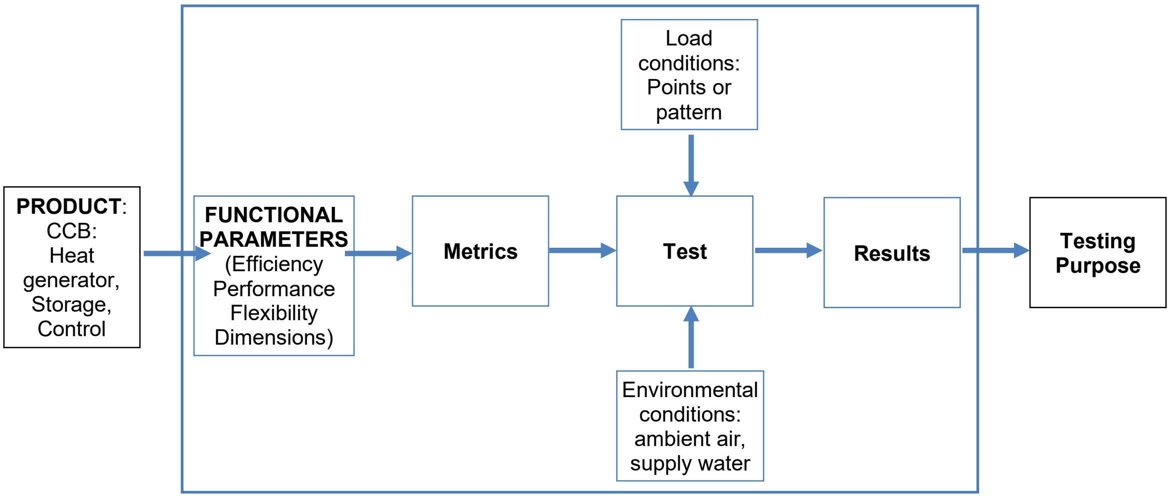


Figure 1. Elements of a Test Method.

For the CCB the **product** is composed of heat generator, storage and control. The interaction between these three elements is essential for the CCB and especially how the control manages to couple the heat generator and the storage to the load requested to the CCB is paramount.

The main **functional parameters** of the CCB are:

- Efficiency (COP)
- Energy consumption
- Performance (water heating, space heating/cooling capacity)
- Flexibility ("smartness")
- Dimensions, weight

Furthermore, costs and price are important. However, these are not functional parameters and usually are not part of standardization work; therefore, they will not be considered here. Also, it is assumed that measurement of dimensions and weight is straightforward – it can be done without operating the product – and need no further attention.
The four types of CCB (flexible, compact, cheap, full featured) can be scored on the basis of the functional parameters. Note that also technical parameters can play a role in characterizing the CCB, e.g. the storage density or the presence of a communication module. In general, technical parameters can be assessed without operating the product, which makes checking on these parameters simpler.

Metrics "connect" the functional parameters with the testing. Note that the metrics are for the functional parameters of the CCB as a whole and not of the individual parts only. Metrics for efficiency, energy consumption and performance can be derived from existing metrics, as for example those for combi-boilers since the CCB provides the same functionality.
This is different for flexibility; the ability to deliver flexibility can be specified, however a metric for (the level of) flexibility is more difficult. This is because the parameter to optimize lies outside the CCB and is part of the situation where the CCB is operated, including the infrastructure.
If it is difficult to find a metric that directly represents a functional parameter, a proxy could be looked for. A proxy is a metric that represents a functional parameter under simplified conditions.

Any measurement method specifies **testing boundary conditions** when measuring the metrics; to be distinguished between:

- **Environmental conditions**: they are determined by the location of the product, not only geographically (climate zone), but also the installation in the building: temperature (of air, supply water), humidity, air speed (draught).
- **Load conditions**: they are determined by the use of the product: for the CCB this is a load pattern or sequence (e.g. tapping pattern, occupation pattern).

For the CCB, both environmental and load conditions are determined by the climate in which the product operates. Regarding the load conditions, in case of domestic hot water production (DHW), the climate is less relevant, while it has a huge impact on the space heating demand, related to the characteristics of the building (insulation, glazing, etc.).
Since the control is an essential part of the CCB, conditions that change over time – especially within the time frame of the storage capacity (24 hours) – are important.

Testing is the activity on a specific unit of the product that results in the values of the metrics. The following two strategies are distinguished:

A. Test only: the measurements deliver the values for the metrics.
B. Test + (model) calculations: test results deliver the input values for the model; the model calculations deliver the results for the metrics.

Strategy A is conceptually simple when applied to a single component but can have serious drawbacks when the complexity of the test object increases as in the case of a CCB. The type of metrics has an influence on testing time, complexity and size of the facilities needed, and as a consequence, on costs.
Regarding testing time, note that each product variant would need a separate full test. If a manufacturer has a CCB with a 50 l, a 100 l and a 200 l storage, in this concept three full tests are needed.

Strategy B could allow for more simple tests thanks to the integration of the simulations; however, it depends on the system tested. The tests can be for the whole system or for single components (heat generator, storage, control). In an ideal case, the available test standards for the heat generator and the storage could be used as input for the model calculations. The challenge is how to take into account the control and the dynamic aspects.
An extended variant of Strategy B is that the model calculations allow for scaling. If a test with a 100 l storage is done, the model could not only calculate results for the CCB with the 100 l storage, but also with a 50 l or a 200 l storage.
Note that a combination of A and B can be used. For some functional parameters a test is performed that (directly) delivers the values for the metrics (Strategy A) whereas for other parameters these results are used to feed a simulation model (Strategy B).

The **testing purpose** will have a large influence on the elements of a test method. Test methods in standards aim to allow a fair comparison of different products, i.e. if the results for the efficiency of two products differ, then this is because the products differ (and not because the load or environmental conditions are different). Furthermore, costs are important since test methods in standards will be commercially used.

Therefore, measurement methods in standards differ from testing approaches for product development, field tests or tests performed by consumer organizations.
We're developing a CCB to have better properties than existing products. A measurement method for CCB's should make the properties at which it excels visible in comparison to products that have not been optimized for these properties.

3 State of the art of existing standards

In this section the most relevant standards for the CCB have been analysed. A full list is reported in Appendix A divided by Countries: Europe, US, Canada, China.
The main objective of the considered standards and regulations is as follows:

- Europe
  - Standards on test methods and performance assessment of heat pumps and their components
  - Standards on the determination of the heat pump sound level
  - Other regulations related with the performance/efficiency of the heat pump (Ecolabel/Ecodesign)
  - Standards relevant to the other components of the CCB (storage, control), rather than the heat pump
  - Standards linked to the CCB application (e.g. buildings energy performance; automation in buildings, passive house)
- Canada:
  - Standards to test the performance of variable capacity heat pumps or heat pumps connected to a storage (i.e. water heater).
- US
  - ASHRAE, AHRI, US DOE test methods and requirements for performance related to heat pumps and air conditioning, water tanks, and thermal storage systems
- China
  - Standards on heat pumps
  - Standards on storage systems

3.1 Performance standards and their comparison

Among all the standards listed in Appendix A for the different Countries, the most relevant that could be used to assess the performance/efficiency of the CCB have been compared on the basis of the following parameters:

- Measurement location (indoor, outdoor, in situ)
- Type of boundary condition (steady state, load file, emulation)
- Test boundary condition (temperatures, flow, etc)
- Output
- Reference climates
- Sequence duration
- Application
- Components included
- Validity

The Tables 1-4 reported include the above-mentioned parameters for the selected standards in the different countries:

- Europe: EN 14825, EN 14511, EN 16147
- Canada: CSA EXP10
- China: JGJ 158-2018, JB/T 12841-2016, GB/t 19409-2013, GB/T 18837-2015
- US: ANSI/ASHRAE 206-2013, ASHRAE 221P, AHRI 1380

Looking at the details collected for the selected standards, it is evident that most of the standards refer only to the heat pump itself, while in some cases both heat pump and storage are taken into account, but only for domestic hot water (DHW) production (e.g. EN16147, CSA EXP10, JGJ 158-2018).
Furthermore, smart control and flexibility are aspects generally not considered in existing standards. Another aspect not included in existing standards is the value of "compactness" of a CCB for its integration in buildings.

For instance, focusing on the EU standard EN 14825, it refers only to the heat pump and foresees some testing points at partial load ratio in space heating mode and in in space cooling mode with fixed compressor speed (controller bypassed). Tests are referred to 3 reference climates and performed in steady state conditions (except if defrost occurs).

The latter aspect represents an evident limitation of the testing method because it neglects the internal control of the HP, that has instead a relevant impact on the HP behavior as shown in Figure 2 where the performance calculated with EN14825 is compared with the performance obtained with the compensation load method [2]. The difference in energy use of a HP tested in steady state or dynamic conditions can range between 5 and 30% depending on the operation conditions.

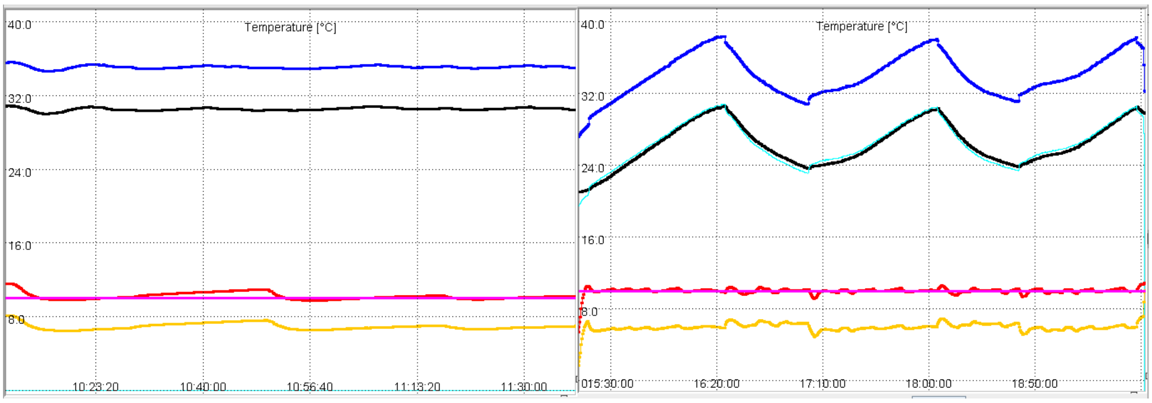


Figure 2. HP performance with fixed compressor speed (EN14825) versus load emulation (compensation load) where the unit can control according to its control.

The EU standard EN 14825 does not consider DHW production, treated in a different standard, EN 16147. The latter includes the definition of a “smart control”, thus it will be further discussed in the next section as an interesting method that could be of inspiration to test the control of CCB systems.

However, it is worth noting that the testing procedure for the control included in EN 16147 is rather complex and takes a long testing period with all the costs and drawbacks that it causes.

Table 1. Comparison Table for Europe

					Boundary conditions				
	Measurement location	**output**	**Calculation of long term performance**	**Test sequence duration**	**measurement boundary condition**	**Reference climates**	**Temperature source**	**Temperature load**	**Load**
EN14825	indoor	performance map at PLR seasonal performance	frequency distribution	"1 hour" per point water source "1.5 hour" per point air source (except defrost)	steady state (except defrost)	Average = Strasbourg Colder = Helsinki Warmer = Athens	Air SH: -15, -7 (-8), 2 (1), 7 (6), 12 (11), 20 (12) Air SC: 27 (19), 35 (24) Water SH: -5, 0, 5, 10, 15 Water SC: 30	Air SH: 20 Air SC: 21 (15), 27 (19), 35 (24) Water SH: 35, 45, 55, 65 Water SC: 7, 18	SH/SC
EN14511	indoor	performance map	not performed	"1 hour" per point water source "1.5 hour" per point air source (except defrost)	steady state	no	Air SH: -15, -7 (-8), 2 (1), 7 (6), 12 (11), 20 (12) Air SC: 27 (19), 35 (24) Water SH: -5, 0, 5, 10, 15 Water SC: 30	Air SH: 20 Air SC: 21 (15), 27 (19), 35 (24) Water SH: 35, 45, 55, 65 Water SC: 7, 18	SH/SC
EN16147	indoor	efficiency DHW cycle	direct extrapolation	1 day 2 weeks for smart function	1day cycle	no	Air: 2 (1), 7 (6), 14 (13) Water SH: 0,10	Water: 40 to 55, Cold water: 10	DHW

	Which component is included?								How flexibility is addressed?			
	heat pump	**Storage**	**ventilation**	**solar thermal**	**pv**	**boiler BU**	**Electric BU**	**Smart control**	**Efficiency**	**Price**	**Demand response**	**other**
EN14825	yes	no	no	no	no	no	no	no	no	no	no	
EN14511	yes	no	no	no	no	no	no	no	no	no	no	
EN16147	yes	yes	no	no	no	no	no	no yes	no yes	no	no	

Table 2. Comparison Table for Canada

					Boundary conditions				
STANDARD	**Measurement location**	**output**	**Calculation of long term performance**	**Test sequence duration**	**measurement boundary condition**	**Reference climates**	**Temperature source**	**Temperature load**	**Load**
CSA EXP10	Indoor	Seasonal COP	Direct Extrapolation (From 24H Sim draw)	1 hr (First Hr Rating), 1 Day (Sim Use. Test)	1 day period (Water draws applied at defined times over 24H period)	Eight Canadian Climate Zones for SCOP calc.	TDB(TWB), in C: -15(-16), 1(-0.6), 20 (13.9), 35 (20.6), TCutOff,HP	TWater,In (in C): 5.6, 8.3, 14.4, 19.4	DHW

	Which component is included?								How flexibility is addressed?					
STANDARD	**heat pump**	**Storage**	**ventilation**	**solar thermal**	**pv**	**boiler BU**	**Electric BU**	**Smart control**	**Efficiency**	**Price**	**Demand rensponse**	**other**	**Validity**	**Note:**
CSA EXP10	Yes	Yes	No	No	No	No	Yes	No	N/A	N/A	N/A	N/A	Canada (Planned, Voluntary)	In Draft form, possibility of evolution of standard and contents over time Profile applied for 1 day draw dependent on first hour rating Testing using default (as-supplied) controls for unit

Table 3. Comparison Table for China

					Boundary conditions				
STANDARD	**Measurement location**	**output**	**Calculation of long term performance**	**Test sequence duration**	**measurement boundary condition**	**Reference climates**	**Temperature source**	**Temperature load**	**Load**
Technical standard for thermal storage air-conditioning system JGJ 158-2018	indoor	Coefficient of performance	direct extrapolation	/	steady state	no	Air SC: 35 Water SC:35（37）	Air SC: 5(10) Water SC:5（10）	SC
Low ambient temperature air source heat pump water heater JB/T 12841-2016	indoor	Coefficient of performance	direct extrapolation	"3 hour" per point air source (expept defrost)	steady state	no	Air SH: 20（Normal temperature conditions） Air SH: -12（Low temperature conditions）	Air SH: 55	SH
Water-source(ground-source) heat pump GB/T 19409-2013	indoor	indoor	indoor	"1 hour" per point water source	steady state	no	Water SC: 30(Water ring),18(Groundwater), 25（Underground pipe、Surface water Water SH: 20(Water ring),15(Groundwater), 10（Underground pipe、Surface water）	Water SC: 7 Water SH: 45	SC/SH
Multi-connected air-condition(heat pump)unit GB/T 18837-2015	indoor	indoor	indoor	"1 hour" per point water source	steady state	no	Water SC: 30(Water ring),18(Groundwater), 25（Underground pipe、Surface water）	Air SC: 27	SC

	Which component is included?								How flexibility is addressed?			
STANDARD	**heat pump**	**Storage**	**ventilation**	**solar thermal**	**pv**	**boiler BU**	**Electric BU**	**Smart control**	**Efficiency**	**Price**	**Demand rensponse**	**other**
JGJ 158-2018	yes	yes	no	no	no	no	no	no	yes	yes	no	
JB/T 12841-2016	yes	no	no	no	no	no	no	no	yes	no	no	no
GB/T 19409-2013	yes	no	no	no	no	no	no	no	yes	no	no	no
GB/T 18837-2015	yes	no	no	no	no	no	no	no	yes	no	no	no

Table 4. Comparison Table for US

STANDARD	Measurement location	output	Calculation of long term performance	Test sequence duration	measurement boundary condition	Reference climates	Temperature source	Temperature load	Load
ANSI/ASHRAE 206-2013		EER, COP, SEER, HSPF, and EF							
ASHRAE 221P		HSP-r, CSP-r, cooling COP	No	>15 minutes	Field operating condition		<40.6C and >17.2 C for cooling test; <18.6C for all heating equipment, but >1.7C for heat pump	between 18C and 24C for heating test; between 21C and 27C for cooling test;	
AHRI 1380		Rating of demand response (DR) ready HVAC equipment	No	NA	NA	NA	NA	NA	NA

	Which component is included?								How flexibility is addressed?					
STANDARD	heat pump	Storage	ventilation	solar thermal	pv	boiler BU	Electric BU	Smart control	Efficiency	Price	Demand Response	other	Validity	Note:
ANSI/ASHRAE 206-2013	Yes	No												standard has a wide range of test procedures and metrics, depending on the capabilities of the equipment under test
ASHRAE 221P	Yes	No												

AHRI 1380	Heat pump and AC with less than 65,000 Btu/hr (19 kW) capacity	No						communication between utility and DR-Ready HVAC		Yes	Yes			This standard describes communication protocols of DR-ready HVAC equipment, and data requirements for published ratings, marking and nameplate data and conformance conditions.

3.2 Standards and regulations related to control, integration and flexibility

In this section a few standards, which contain interesting elements for the CCB because related to smartness of control, system integration and flexibility/smart grid readiness, are further described:

- **EN16147 (EU)**: this standard proposes a method to take into account **the smartness of the control** on the water heater. It has been developed in the framework of the ecolabel/eco-design of electric water heaters and, on the basis of a given testing profile, it aims at assessing the performance of the tested system in comparison with the system with a basic control.
  A Smart Control Factor (SCF) is defined:

$$SCF = \left(1 - \frac{Q_{elec}^{smart}}{Q_{elec}^{ref}}\right)$$

- **EN12977 (EU):** the standard refers to **custom built solar heating systems,** uniquely built or assembled by choosing from an assortment of components. The components are separately tested and test results are integrated to an assessment of the whole system. The standard provides detailed reference conditions to compare the performance of different systems (about system specification, weather data, DHW load, SH load). The components parameters are identified through **experimental tests** (specified for solar collector, thermal storage, control system...) and used to validate a **dynamic simulation** model used to assess the energy performance of the overall system. It exemplifies the combination of different evaluations approaches when complex systems made by different components are considered, as for the CCB.

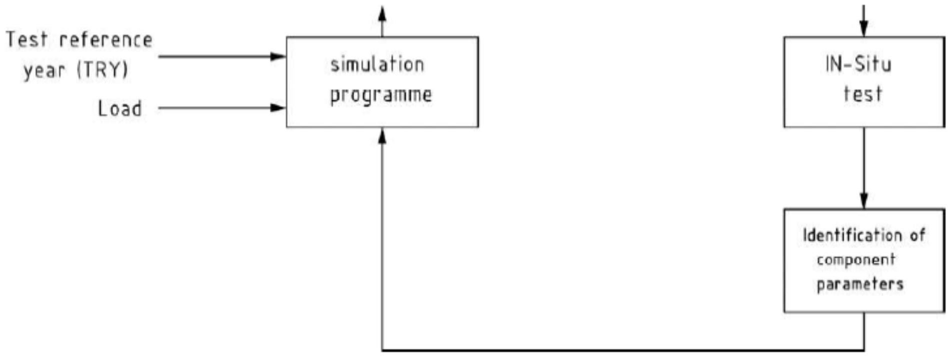


Figure 3. Combined experimental and simulation testing method (EN12977).

- **AHRI 1380 (US)**: this standard wishes to regulate **the participation of variable capacity heat pumps systems in Demand Response (DR) programs.** It mostly addresses the problem of communication protocols and minimum requirements. It is an example of how to rate the CCB functionalities for its energy flexible applications.
- **EN 15232-1 (EU)**: the standard wants to quantify the **impact of the Building Automation and Control system (BAC) on the energy performance of the building** itself. Firstly, all the functions of a BAC that could affect the building performance are listed (i.e. possible control actions on the emission system or generation system, having identified some configurations of heating/cooling systems) and then classifies the BAC in different efficiency classes on the basis of the functions that it includes.
  Two approaches are proposed to calculate the impact of the BAC: (i) a detailed method or (ii) a BAC factor method.
  The detailed method refers to other standards where the different elements of the heating/cooling system are analyzed in detail. The BAC impact can be quantified differently on the basis of the considered standards approach, which can be: direct approach; operating mode approach; time approach; setpoint approach; correction coefficient approach.

  The factor-based calculation procedure of the BAC impact, instead, is a simplified method where BAC efficiency factors are defined for each BAC class.

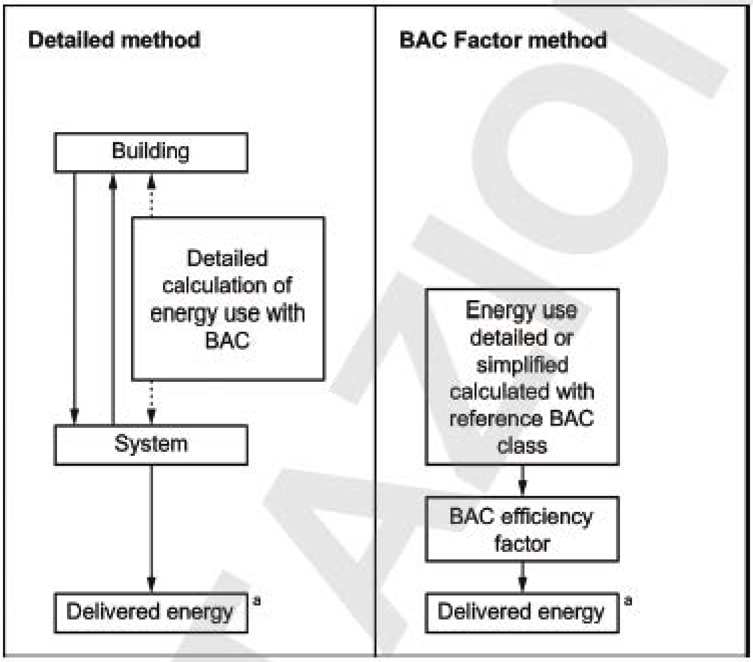


Figure 4. BAC evaluations methods (EN 15232).

The standard EN15232 deals with the topic of the control, which is one of the most difficult aspect to take into account in the assessment of a CCB at the moment, and it provides useful suggestions to rate a system on the basis of the functionalities that it includes.

- Similarly, the definition of the **Smart Readiness Indicator** for a building can be taken into consideration as source of inspiration to take the aspect of smartness of a technology into consideration when evaluating its functionalities.

  The concept of the Smart Readiness Indicator has been introduced by the Energy Performance of Buildings Directive (EPBD 2018/844). The SRI has been defined as: "Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants".

  The methodology proposed to calculate the SRI is based on the smart ready technologies available [1]. Catalogues of smart ready services have been compiled, they list the relevant services and describe their main expected impacts towards building users and the energy grid. Many of these services are based on international technical standards. In accordance with the requirements from the revised EPBD, three key functionalities of smart readiness in buildings have been taken into account when defining the smart ready services in the SRI catalogue: 1. The ability to maintain energy efficiency performance; 2. The ability to adapt its operation mode in response to the needs of the occupant. 3. The flexibility of a building's overall electricity demand.

  In the SRI service catalogues developed, services are structured within nine domains: heating, cooling, domestic hot water, controlled ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging and monitoring and control. For each of the services, 2 to 5 functionality levels are defined. A higher functionality level reflects a "smarter" implementation of the service.

  The impact criteria are: Energy savings on site; Flexibility for the grid and storage; Comfort; Convenience; Well-being and health; Maintenance and fault prediction; Information to occupants.

  The methodology proposes also to convert the SRI in another aggregated indicator that can weigh the impact of the different domains. Further details can be found in [1].

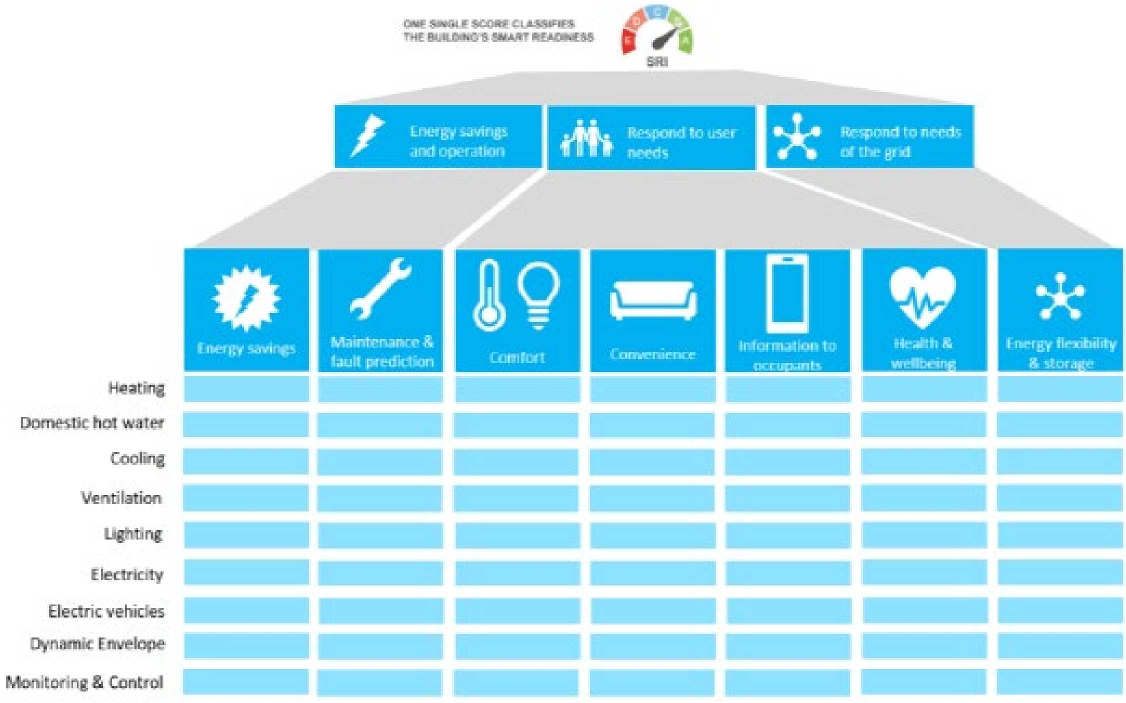


Figure 5. SRI Assessment matrix [1]

3.3 Testing methods under development: dynamic tests

3.3.a Dynamic components test

The existing standards to assess the performance of the heat pump foresee to test the unit with fixed speed of the compressor under full load and (in some cases) part load. The efficiency of the heat pump that is measured from those testing procedure does not consider the effect of the heat pump controller. These aspects are particularly relevant for the CCB because it integrates more components and the control of the system plays a paramount role.
Actually, the Canadian standard CSA EXP07 (Test Standard for Variable Capacity (Air-Air) Heat Pumps) is an example of dynamic testing method, given that it uses a testing load profile designed to capture both the maximum capacity and the ability of the heat pump to modulate (see Appendix A).
Other approaches under developed are for example the “compensation load” test, developed by BAM, which takes into account the control of the heat pump [2], [3]. During the test the heat pump is allowed to modulate and the boundary conditions are given in accordance with climate data in EN 14825.
Eurac has defined a component dynamic test where the boundary conditions are defined from the simulation of a reference system and a representative sequence is selected with a bin classification [4], [5].

3.3.b Dynamic whole system test

In the last years, different whole system test procedures have been developed to test solar thermal combi systems [6] namely CCT [7], PLPE [8], Combitest [9], SCSPT [10], DST and so on. Some of these test procedures evolved to test heat pump systems of different typologies (solar thermal + heat pump, PV+HP and so on). As mentioned above, the dynamic whole system test approach could also apply to the integration of components in the CCB, therefore it is worth mentioning these procedures.
The common approach of these methods is to test the whole system considering a short sequence (of 6 or 12 days) and the emulation of the boundary conditions.

As general approach, the system is installed as a whole in the laboratory including all the components that are present in the technical room of the building while the load and the components that are not installed are emulated in real time. A short sequence reproduces the boundary conditions of the tested system in order to represent the entire year. As an example, Figure 6 shows a solar assisted heat pump system that was design for space heating, space cooling and domestic hot water preparation.

The red line represents the "test boundary" that is the part installed in the laboratory, while the black line represents the "heating and cooling system boundary". The system coupled to a climate and to a building gives the application (and this boundary is indicated with green line).
The data recorded during the test is used to analyse the system performance under dynamic working condition and to extrapolate the seasonal performance of the whole system.

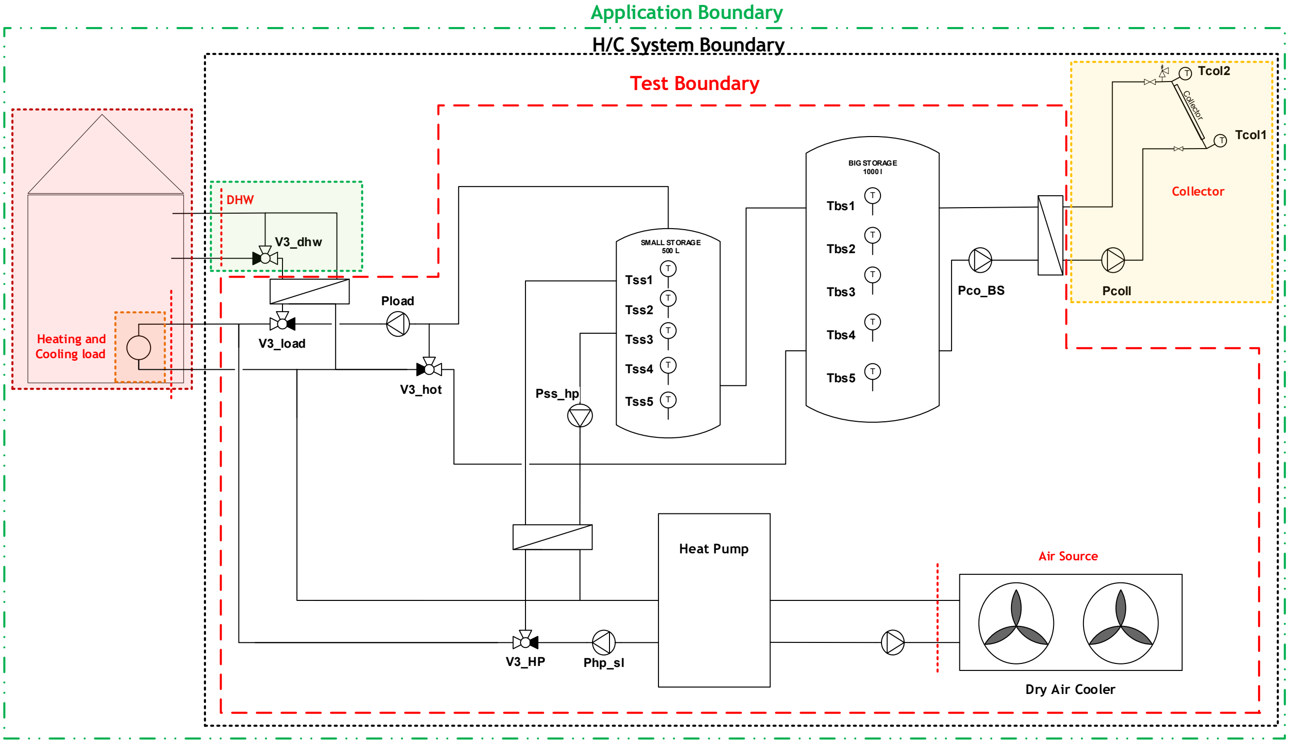


Figure 6. Whole system tests configuration.

The general approach explained previously has been implemented differently by the different methods. The differences can be identified in the following steps.

- Selection of the test sequence.
  - Data grouping (bin, monthly average, clustering): the days of the year are grouped in different groups. The number of groups defines the sequence length and the representative day of the group is used to build the sequence [4], [11].
  - Optimization: a simulation tool is used to define an optimized sequence that satisfy some requirements of the test sequence as e.g. the proportionality between the sequence performance figures and the yearly performances [12].
- Load definition.
  - Fixed load file: a load file defines the boundary conditions of the system. The load file can be defined as a "power profile" or "energy profile" or as "temperature time series".
  - Building emulation: the load can be simulated in real time giving the return temperature that depends on the behaviour of the system.
  - Hybrid approach: both the load file and the building emulation are used to define the load. The load file limits and fixes the amount of energy exchanged by the system.
  - This approach is usually implemented for benchmark purposes (different system are tested with the same load).
- Emulation of the components that cannot be installed in the lab.
  - Fixed dynamic boundary conditions: time series of temperature, flow rates and other boundary conditions are defined with a dynamic simulation. Those boundary conditions are than used for different systems.

    - Hardware in the loop (TRNSYS in the loop, simplified models): a real time simulation is used to emulate the component that cannot be installed in the lab. The supply temperature and the flow rate of the system is measured and given as input to a numerical model. The model with other parameters simulates the behaviour of the component and gives as output the return temperature. The laboratory takes this value as reference for the control of the return temperature.
- Extrapolation of the seasonal performance from the test sequence.
    - Direct extrapolation: the seasonal performance is defined with a direct extrapolation (that can be a simple proportion or a weighted proportion).
    - Simulation (black box model or grey model): the data collected from the test is used to validate a system that simulates the seasonal boundary conditions. From the simulation results the seasonal performance are defined.
- Extrapolation of the seasonal performance to other climates or load conditions:
    - No extrapolation: some procedures do not foresee any methodology for the extrapolation of results to other climates or load conditions.
    - Tables: the extrapolation is done with tables or graphs.
    - Simulation (black box model or grey model): the data collected from the test is used to validate a system that simulates other climates or load conditions.
- Applicability of the methodologies (system typologies, climate or load conditions): the combination of previous points defines the possibility to apply the procedure to different system layout or to test the same system with different load/climate conditions (that is different from extrapolate the performance to different load conditions).

  Some choices can be obstacles for the applicability to different conditions as the definition of the test sequence from an optimization performed simulating only one system typology. In this case the sequence is good performing for that system typology but can be not appropriate for other systems.

In Table 5 the main specifications of the existing dynamic testing approaches are reported.

Table 5. Specifications of the different dynamic tests methods

	measurement boundary condition	output	Calculation of long term performance	Emulation	Reference climates	Test sequence duration	Temperature source	Temperature load	Load	HP	TES	Ven	Solar (thermal or PV)	Boiler BU	Electric BU	Control	Application
P+LPE	dynamic (real time emulation)	seasonal performance factors	direct extrapolation	with simplified emulations load files	Applicable to different climates	6day - core sequence	variable according to weather file	variable according to emulation	SH SC DHW	yes	yes	no	emulated	yes	yes	yes	Solar thermal system + heat pumps Solar cooling Heat pump systems
CCT	dynamic (real time emulation)	seasonal performance factors	direct extrapolation	with TRNSYS	Zurich	6day - core sequence	variable according to weather file	variable according to emulation	SH DHW	yes	yes	no	emulated	yes	yes	yes	Solar thermal system + biomass Solar thermal system + heat pumps Heat pump systems
SCSPT	dynamic (real time emulation)	seasonal performance factors	direct extrapolation +ANN	with TRNSYS	Zurich + other 2	6day - core sequence	variable according to weather file	variable according to emulation	SH DHW	yes	yes	no	emulated	yes	yes	yes	Solar thermal system + biomass Solar thermal system + heat pumps Heat pump systems
Combitest	dynamic (fixed load)	seasonal performance factors	direct extrapolation	with TRNSYS load file	Zurich	6day - core sequence	variable according to weather file	variable according to emulation	SH DHW	yes	yes	no	emulated	yes	yes	yes	Solar thermal system + biomass Heat pump systems
DST	In situ		Simulation	On field test													Solar heating – DHW systems

Sources: [6], [8], [13]–[17]

3.4 Shortcomings in existing standards

Based on the analysis of existing standards, it is evident that the existing legislative framework currently does not provide specific requirements for CCBs. International standards perform evaluations on component level under given conditions and calculate the seasonal coefficient of performance of the unit based on a statistical monthly outdoor air temperature, standardised thermal load profiles, standardised heat distribution systems or standardised domestic hot water usage. The interaction of the CCB with the building conditions (loads for space heating, hot water, cooling; climate conditions; PV or solar thermal data, electric grid) is currently not considered in the standards and need to be addressed in the calculation of the performance of the CCBs in the future. **Actual standards only enable the evaluation of the performance on component level instead of considering different components as one system**. Some provide calculation procedures for some combinations of systems (e.g. EN 15316-4-2 which covers space heating and DHW preparation in simultaneous operation. Part 4-3 also covers solar thermal and PV systems but there is no possibility for combination mentioned).

Referring to the European standards, EN 14511 and EN 14825 consider heating and cooling modes, whereas EN 16147 deals with DHW preparation and is the only standard which includes control strategies. These standards are not suited for the evaluation of the performance of CCBs, since these do not cover the combination of space heating, DHW production, storage, cooling, as well as control strategies. Existing standards require revision or extension to adapt to the requirements of CCBs, i.e. to represent the dynamic interaction of different components.
The comparison of CCBs with **existing standards** shows that they **do not contain any calculation methods that include both heating, cooling, hot water preparation and flexibility in the form of control strategies**. Only the standard EN 16147 includes both the HP, the storage and the control, but it refers exclusively to DHW production. It could be considered as the closest standard to rate a CCB. However, in order to include also heating and cooling production, the testing method should be adapted to the space heating/cooling demand load: representative testing loads for heating and cooling demand should be defined. Furthermore, the testing method as it is now taking a long testing period (2 weeks), producing high costs for its execution. A shorter testing period to decrease costs should be evaluated. It is worth mentioning that the more complicated the component/system is, the more testing is required. It is unavoidable, but an effort can be made in trying to reduce as much as possible time and complexity of the test rig. Based on that, normally it is better to refer to standard loads rather than extra simulations because it increases too much time for standard testing.

Like in Europe, there are no existing standards that can be directly applied to a CCB. ANSI/ASHRAE Standard 206-2013 (RA 2017) specifies methods of testing multipurpose heat pumps for residential space conditioning and water heating. Although the multipurpose heat pumps can provide multiple functions simultaneously or alternatively, their functions are for meeting the instantaneous thermal loads for space conditioning and water heating. **This standard does not include any performance evaluation for thermal storage and load shifting**. However, the multipurpose heat pumps can provide active thermal storage using hot water tank, e.g., heat the water tank to a higher temperature in the evening to store more heat in the water tank and reduce or eliminate water heating operation of the heat pump during the day, which can help reduce the peak electric demand resulting from water heating operation. The standard can be extended to include the active thermal storage with the water tank for water heating. Further extensions are needed to include other functions, such as storing thermal energy for space cooling and space heating.
ASHRAE Standard 221P describes the method for measuring in the field (e.g., building site) the cooling and heating performance of an installed unitary HVAC system. The standard is for unitary HVAC systems with forced-air distribution. It does not include any performance evaluation of thermal storage systems or for the HVAC system using hydraulic system, such as radiators or fan coils. This standard could provide useful guidance for field measurement of CCB's performance if it is extended to include methods for evaluating the thermal storage capacity, and the charging and discharging performance (e.g., supply fluid temperature from the thermal storage and the duration of discharging the stored energy at desired temperature).

AHRI Standard 1380(IP) (2019) defines communication, infrastructure, and system functionality relate to the implementation of energy management strategies for variable capacity DR-ready HVAC systems installed in residential and small commercial applications with capacities of 65,000 Btu/hr or less (i.e. <20 kW). It can be applied to CCB if it is used to provide active demand response through thermal storage.

Table 6. Shortcomings in existing standards

Standard	Description	Shortcomings
EN 14825	Determination of seasonal coefficient of performance for heating and cooling mode in part load conditions	It does not include combination of space heating and DHW production. Even in part load, the test is performed for fixed steady state conditions. The onboard HP control logic is neglected
EN 14511	Rating the performance of heat pumps for space heating and cooling	Only heating and cooling modes are considered, there is not combination with DHW production. No method to calculate the seasonal coefficient of performance. Only steady state tests.
EN 16147	Performance rating for DHW units	It considers only DHW production. A dynamic testing method is included to assess the impact of the control strategy but it takes 2 weeks.
ANSI/ASHRAE Standard 206-2013	Methods of testing multipurpose heat pumps for residential space conditioning and water heating	It considers the combination of space heating and DHW production, but it does not include the possibility of using active storage. Performance evaluations for thermal storage and load shifting are not included
ASHRAE Standard 221P	Method for measuring in the field (e.g., building site) the cooling and heating performance of an installed unitary HVAC system	It does not include any performance evaluation for thermal storage system, e.g. the thermal storage capacity, and the charging and discharging performance
AHRI Standard 1380	Communication, infrastructure, and system functionality for DR	Limited to units <20 kW It is limited to the US market

4 Suggestions to overcome existing limitations

The most relevant shortcomings highlighted in the review of the existing standards are linked to the difficulty in representing all the services provided by a CCB and in particular its dynamic behaviour. Such dynamic behaviour is important for a realistic performance assessment both at component level and for the integration of the different components in the CCB. Furthermore, it is paramount for the energy flexibility evaluation.
The challenges in the assessment of CCBs are related to the following points:

- the energy performance: existing standards neglect the dynamic behaviour of the system and do not take into account the control on board. The latter point is particularly relevant for a CCB where not only the heat pump, but also a thermal storage is included: the charging and discharging process is always transient so the dynamic performance of the heat pump and the TES should be accounted for when evaluating energy performance.
- the energy flexibility: it is not measured or assessed by any existing testing method and, given that it depends on the internal and external boundary conditions, its quantification is rather difficult.
- The energy flexibility is determined in part by the energy storage capacity (the product of energy storage density and storage volume) and the quality of energy storage (i.e., the temperature of the stored energy). The energy storage capacity is affected by the heat pump capability and functionality. Both HP and TES should be accounted for when evaluating the energy flexibility.
- the Smart Grid Readiness: in order to exploit the energy flexibility of a CCB, especially in case of participation to Demand Response programs, it is important that the CCB can communicate with different systems installed on site and/or with the building automation and control and/or with external parties (e.g. utilities, aggregators, etc.). At the moment there are not clear protocols and standards adopted by all the suppliers and this limits the possibility of interconnectivity of these systems.

In the section below some suggestions to overcome the existing shortcomings are discussed.

4.1 Standards on energy performance assessment for CCB

Some suggestions to improve the existing standards to rate CCBs are:

- Development and proposal of solutions for highly integrated hybrid systems comprising several heat/cold sources that are composed of different components that are usually tested and rated separately, but cannot be separated anymore from the integrated system. The method should take into account interaction between components, control and storage stratification.
- Elaboration of solutions for missing component performance identification, such as thermal storage stratification and heat losses of combi stores that are not at a uniform temperature in real life. Indeed, the temperature stratification of the storage is a decisive factor for the overall efficiency of a CCB. Haller et al. [18] have proposed a test method to determine the storage stratification and they have introduced a key performance indicator for stratification efficiency, based on the second law of thermodynamics. The laboratory test is based on a 24-hour cycle where realistic and dynamic charging and discharging is applied according to boundary conditions of real weather data of a day in the year.
- Implementation of dynamic testing procedures for heating systems allowing not only the determination of seasonal efficiency, but also emission factors at the test bench.
- Implementation of communication protocols for the CCB to communicate with demand side management signals of the grid operators, the forecast of building thermal loads, and other signals/inputs for optimizing the control of the CCB. AHRI 1380 can be used as a reference for the communication protocols of DR-ready HVAC equipment.

Eventually another approach to assess the CCB performance could be to use the **Package label**, as defined for the solar thermal industry, where it is typical to have more components combined together [19].

The "package label" is the label applicable to a system, i.e. the combination of different components of a system. The installers who offer for sales a combination of, for instance, a solar thermal system with a conventional boiler from different suppliers will have the obligation to indicate in their commercial proposal (quote, final offer, etc.) the energy efficiency and energy efficiency class of the proposed combination. While the product label and preassembled/standard packages, constituted by products from the same manufacturer are provided by the manufacturer, the package label of custom-made packages, designed to meet the needs of one specific consumer, has to be calculated and issued by the dealer or installer – whoever makes the sale. For this purpose, there are calculation tools under preparation to rate the performance of combined systems (see the EU funded project LabelPack A+ [19]).

4.2 Design energy flexibility assessment

4.2.a Theoretical approach

The objective is to provide a simple preliminary methodology to identify and quantify the design flexibility potential of a CCB system. Given the difficulty in assessing the flexibility in real operating conditions, we focus here on a "**design flexibility**", i.e. the flexibility that a system can provide and that is strictly linked to its design specifications. Therefore, the flexibility quantification should take into account two contributions: (i) **the CCB autonomy**, i.e. the time in which active thermal energy production can be switched off and the amount of load shifted and (ii) **the rebound effects connected to the flexibility activation**, i.e. the energy use and energy efficiency variations.

The method should be possibly independent of the energy demand of the building in which it is installed, because it has to characterize the flexible behaviour of the CCB and **to allow a comparison among different CCBs from different manufacturers**. In order to introduce a standardized methodology of evaluation, a simple approach is proposed where the above-mentioned contributions (autonomy and rebound effect) can be assessed separately.

The CCB autonomy can be evaluated considering a scenario in which the thermal energy storage (TES) is initially completely charged and it is calculated how long it can meet the demand with the HP switched off ($\Delta \mathbf{t}_{\mathbf{discharge}}$). On the other hand, the rebound effects can be evaluated during the charging phase of the TES (at the beginning completely discharged) when there is no thermal demand from the building.

In the following it is described a proposed standardized methodology to assess such a design flexibility. As known the energy flexible behaviour is strictly connected to boundary conditions, thus they are specified in a unique way so to make the procedure replicable. The scenarios considered and the modelling approach are described and the obtainable results are discussed by means of a numerical example.

The focus will be mostly on space heating (SH) applications where the TES is a water storage tank, however the method can be used and extended to space cooling and DHW production, presence of back up heaters and thermal energy storage with phase change materials.

Boundary conditions:

- **Weather data.** A fixed value for the outside temperature is considered (T_{out}).
- **Heat pump.** With reference to a commercial heat pump (HP), the COP in different operating points is known from data declared by the manufacturers. In particular:
  - for fixed speed heat pump (on-off regulation) it is known the function $COP(T_{out}, T_{sup,HP})$ where $T_{sup,HP}$ is the required supply temperature of the heat pump (boundary condition).
  - for variable speed heat pump, it is known the function $COP(T_{out}, T_{sup,HP}, CR)$, where CR is the capacity ration of the variable load heat pump. The capacity ration can be defined as the thermal power required at the heat pump ($\dot{Q}_{HP}$) in the specific operating conditions ($T_{out}, T_{sup,HP}$) divided by the maximum thermal power declared ($\dot{Q}_{max,HP}$), referring to the same operating temperatures ($T_{out}, T_{sup,HP}$):

$$CR = \frac{\dot{Q}_{HP}(T_{out}, T_{sup,HP})}{\dot{Q}_{max,HP}(T_{out}, T_{sup,HP})}$$

  To obtain COP in operating conditions other than those declared by the manufacturer, it is possible to operate by interpolating data.
- **Building thermal demand for space heating (SH)**. A fixed value is considered ($\dot{Q}_{SH}$) for the space heating thermal demand (SH). In order to make the evaluation independent from the building characteristics, it is assumed as a percentage (p_{SH}) of the maximum thermal power declared ($\dot{Q}_{max,HP}$).

$$\dot{Q}_{SH} = p_{SH} \cdot \dot{Q}_{max,HP}$$

- **Thermal energy storage (TES) specifications.** For sensible thermal energy storages (i.e. water tanks), the size of the TES (V_{tank}), the thermal losses coefficient ($Loss_{tank}$) and starting state of charge are known.
- **Control strategy**. Supply temperature of the HP ($T_{sup,HP}$) and supply temperature for SH ($T_{sup,SH}$). Design temperature difference between supply and demand in both HP and SH water circuit ($\Delta T_{HP,design}$ and $\Delta T_{SH,design}$).

- **DSM strategy**. Since the objective is to show the capability of the CCB to be flexible. The charging and the discharging phases of the TES are considered separated. The analysis of the charging phase allows to evaluate how the TES affects the overall energy consumption. While the assessment of the discharging phase allows to evaluate the potential CCB autonomy.
- **Hydraulic configuration.**

Modelling approach

A simplified modelling approach is considered, that could be implemented without any dynamic simulation tool (e.g. with an excel spreadsheet).

Considering a sensible thermal energy storage, the hot water storage tank can be assumed to be a perfectly stirred water tank, i.e. all the water in the tank is described with **a single temperature T_{tank}**. (Note that this assumption has an impact especially on the charging phase of the TES. It is reasonable for space heating in case of not small storage volumes. A thermally stratified tank would be necessary to represent the DHW storage. Even if more complex, a tank with different thermal nodes can still be simulated without dynamic simulation tools).

The energy balance of the TES can be written as:

$$V_{tank} \cdot c_w \cdot \rho_w \cdot \frac{dT_{tank}}{dt} = \dot{Q}_{HP} - \dot{Q}_{SH} - \dot{Q}_{loss}$$

Where $\dot{Q}_{loss}$ are the thermal losses towards the external environment (T_{env}):

$$\dot{Q}_{loss} = Loss_{tank}(T_{tank,avarage} - T_{env})$$

The discretized version of the law of energy conservation for the storage can be rewritten as:

$$V_{tank} \cdot \rho_w \cdot c_w \cdot \frac{T_{tank}(t + \Delta t) - T_{tank}(t)}{\Delta t} = \dot{Q}_{HP}(t) - \dot{Q}_{SH}(t) - \dot{Q}_{loss}(t)$$

where Δt is the timestep. To evaluate the thermal losses an average temperature at each timestep is considered:

$$T_{tank,avarage}(t) = \frac{T_{tank}(t + \Delta t) + T_{tank}(t)}{2}$$

The thermal power of heat pump ($\dot{Q}_{HP}$) can be calculated with: $\dot{Q}_{HP} = \dot{m}_{HP} \cdot c_w \cdot (T_{sup,HP} - T_{ret,HP})$

Where $\dot{m}_{HP}$ is the water flowrate of the HP (kept constant), $T_{sup,HP}$ and $T_{ret,HP}$ are the water supply and return temperatures in the HP circuit. The numerical value of $\dot{m}_{HP}$ can be calculated as the flow rate that allows the maximum heat capacity of the heat pump ($\dot{Q}_{max,HP}$) for the required operating conditions ($T_o, T_{sup,HP}$) to be exchanged with a certain temperature difference ($\Delta T_{HP,design}$):

$$\dot{m}_{HP} = \frac{\dot{Q}_{max,HP}}{c_w \cdot \Delta T_{HP,design}}$$

Discharging phase

The discharging phase takes place with the heat pump off. Initially the TES is completely charged, i.e. it is at the maximum supply water temperature of the HP ($T_{sup,HP}$) and it is considered discharged when it reaches a minimum allowed value, which is assumed to be equal to the minimum supply water temperature to the SH ($T_{sup,SH}$).

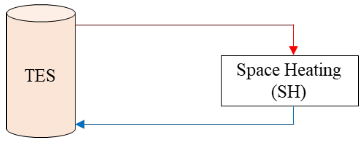


Figure 7. Schematic of the CCB: (a) discharging phase.

The equation of the TES can be rewritten as:

$$V_{tank} \cdot \rho_w \cdot c_w \cdot \frac{T_{tank}(t+\Delta t) - T_{tank}(t)}{\Delta t} = p_{SH} \cdot \dot{Q}_{HP,max}(t) - \dot{Q}_{loss}(t)$$

The TES is considered discharged when it reaches the minimum temperature ($T_{sup,SH}$).

Metrics: It is possible to evaluate the duration of the discharging phase ($\Delta t_{discharge}$) and the useful thermal energy delivered to SH.

Charging phase

Initially the TES is completely discharged: it is at the minimum supply water temperature to the space heating SH ($T_{sup,SH}$) and it is considered charged when it reaches the maximum set point, which is assumed to be equal to the maximum supply water temperature of the HP ($T_{sup,HP}$).It is assumed that during the charging phase there is no energy demand from the building.

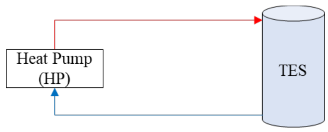


Figure 8. Schematics of the TES charging phase

The equation of the TES can be rewritten as:

$$V_{tank} \cdot \rho_w \cdot c_w \cdot \frac{T_{tank}(t+\Delta t) - T_{tank}(t)}{\Delta t} = \dot{Q}_{HP}(t) - \dot{Q}_{loss}(t)$$

At each timestep t: $T_{tank}(t) = T_{ret,HP}(t)$

By imposing that the heat pump must produce water at a certain temperature ($T_{sup,HP}$), the thermal power that the HP should produce to reach that temperature is calculated:

$$\dot{Q}_{HP,calc}(t) = \dot{m}_{HP} \cdot c_w \cdot \left(T_{sup,HP} - T_{tank}(t)\right)$$

Metrics: In this way it is possible to evaluate the duration of the charging phase (Δt_{charge}) and, knowing the HP performance provided by manufacturers, it is also possible to assess the electricity consumption (E_{HP}) and the COP trend.

Numerical Example

- Brine/water heat pump with rated power of 6kW at -10°C for an average climate
- The heat pump performance are provided by the manufacturer and assessed on the basis of EN 14511 & EN 14825. A variable capacity heat pump is considered.
- Thermal energy storage: 200l for space heating.
- Standing losses according maximum boundary of energy class B: $Loss_{tank} = \frac{12+5.93 \cdot V^{0.4}}{45} \left(\frac{W}{K}\right)$
- The building thermal demand during discharging is assumed equal to the heat pump rated power at the considered outdoor temperature.
- The outdoor temperature is assumed constant and equal to one of the testing temperatures for the heat pump performance (-7, 2, 7 or 12°C).

  The calculation is repeated for each of the above outdoor temperature and then average metrics to assess the flexibility are calculated as follows (note: different weighs could be considered to take into account the distribution in time of the outside temperature):

- Sum of all charging & discharging times:

$$t_{flex} = \frac{\sum_1^4 (t_{charge} + t_{discharge})}{4}$$

- Sum of useful heat:

$$Q_{useful\ flex} = \frac{\sum_1^4 (Q_{useful})}{4}$$

- Sum of consumed electricity:

$$P_{electricity\ consumption\ flex} = \frac{\sum_1^4 (P_{elec})}{4}$$

- COP during flexibility provision:

$$COP_{flex} = \frac{Q_{useful\ flex}}{P_{electricity\ consumption\ flex}}$$

- Calculation of reference COP:

$$COP_{ref} = \frac{\sum_1^4 COP_{provided\ by\ CCB\ manufacturer}}{4}$$

Reported metrics:

- Efficiency of the provided flexibility:

$$\eta = \frac{COP_{flex}}{COP_{ref}}$$

- Average time to charge TES:

$$t_{charge} = \frac{\sum_1^4 t_{charge\ flex}}{4}$$

- Average time to discharge TES:

$$t_{discharge} = \frac{\sum_1^4 t_{discharge\ flex}}{4}$$

Results:

t flex (min)	176.32
η (%)	70.21%
t charge (min)	46.40
t discharge (min)	129.92

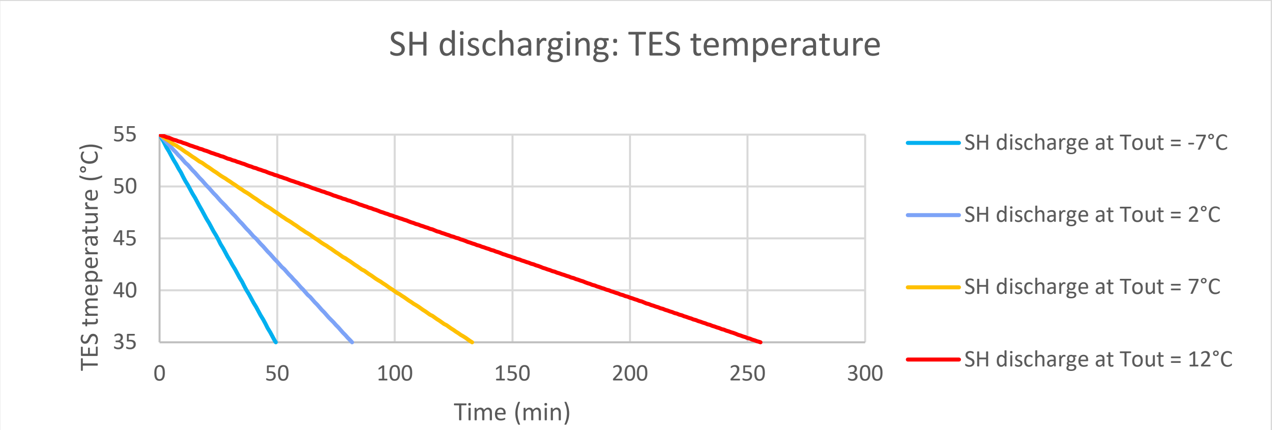


Figure 9. TES temperature during discharging at different outside temperatures.

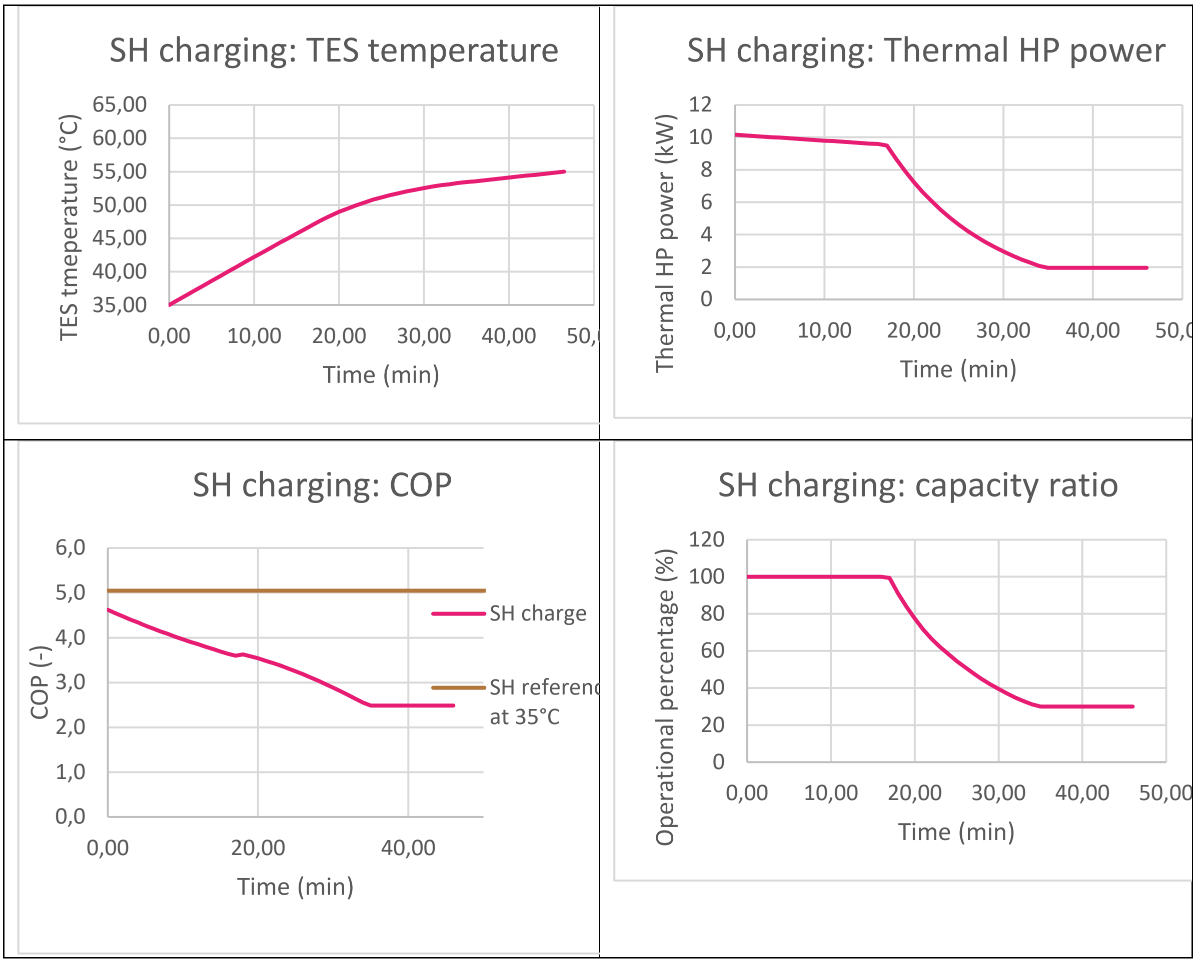


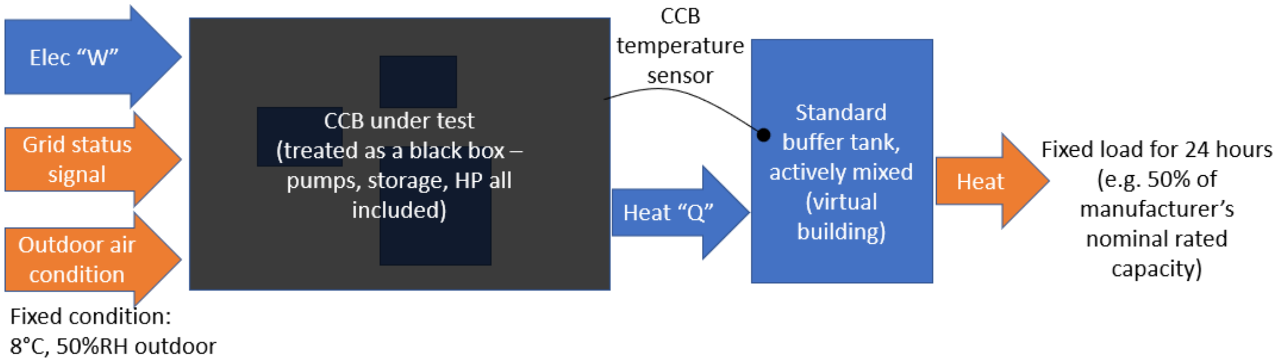
Figure 10. Results of the application of the flexibility method to the numerical example considered (Outdoor temperature -7 °C). The thermal power decreases when the HP modulates its load while the storage full load capacity is approached.

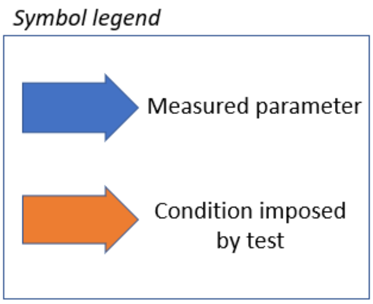
4.2.b Experimental approach due to the lack of an integrated testing standard for CBB type of technology

In order to test the performance of the CCB taking the role of all the components into account (HP, storage and control), a testing procedure is suggested where the CCB is treated as a black box. Two pieces of information about the CCB are required to be supplied by the manufacturer: the nominal capacity, and the nominal storage duration.
The testing conditions are not representative of “real world” operation, but they are meant to provide a repeatable benchmark against which CCB products from multiple manufacturers can be compared.
The CCB is connected to an external thermal storage representing a virtual building. The thermostatic sensing device of the CCB is installed in this external storage vessel, so that the external storage is maintained at a fixed temperature by the CCB. During the test, a fixed thermal load is drawn from the external storage vessel (see Figure 11). Such thermal load has to be defined as boundary condition in the testing procedure (e.g. 50% of the manufacturer’s nominal rated capacity).
The manufacturer should declare the duration of storage the CCB can provide at nominal capacity. Each of the three phases of the test (“Normal”, “Off Peak” and “On Peak”) is then set to be twice the nominal storage duration. The only thing that changes during these modes is the grid status signal provided to the CCB. The CCB operates entirely based on its own internal control logic, and the tester need not have any visibility into these internal calculations. . In order to do so each CCB has to have a testing mode compatible with these three standardized modes.

The energy consumption is measured in each operating mode and the energy flows into and out of the device are measured. Based on these, various metrics such as COP, SPF, etc. can be derived. By comparing the performance in the different modes, it is possible to assess the variation of the efficiency when a flexible strategy is activated.

In order to be sure about the initial state of charge of the TES in the CCB, a first preparation cycle to fully charge or discharge it is necessary. This testing approach could be used to compare CCBs including different control/storage. It does not consider the flexibility deriving from the users demand. The latter aspect is interesting in real applications, but it is not suitable for performance assessments as those foreseen in standards or similar reference methodologies.





Test summary

	Normal 8 hour period	On peak 8 hour period	Off peak 8 hour period
Test elapsed time	0 – 8 hr	8 – 16 hr	16 – 24 hr
Grid status signal provided	Normal	Off peak	On peak
Energy consumption	W_N	W_C	W_D
Heat provided	Q_N	Q_C	Q_D
COP	$COP_N = Q_N / Q_N$	$COP_C = Q_C / Q_C$	$COP_D = Q_D / Q_D$

Figure 11. Example of the experimental testing method of a CCB (referred to an 8 hours storage).

5 Conclusions and suggestions

Conclusion:

In this report a review of existing standards to rate the performance of the components included in the CCB have been performed. Given the relevance of standards to propose a fair rating and comparison of different CCBs, the purpose of this report was to highlight possible shortcomings in existing standards that do not allow to take into consideration the peculiar aspects of a CCB. Being the CCB a system where more components are integrated and where the control strategy and storage capacity for flexibility purposes are very relevant, it has been noted the importance of well accounting for the dynamic behaviour of the components involved. The neglection of system dynamics is also important to assess the performance of simple components, but it is even more necessary to take into account the interaction of different components under specific control strategies.

Suggestions:

Above mentioned aspects have been critically discussed in the report and some suggestions to overcome the existing limitations have been proposed; In particular existing standards used for different applications have been highlighted as possible references for CCB (e.g. EN 16147 or SRI), while simple methods to account for CCB dynamics and flexibility (analytically or experimentally) have been elaborated. It is recommended to commence more development on establishing a strictly defined reference for CCB testing as a physical unit. Accompanied by standards for determination of the dynamics and flexibility with CCB in smart grid applications

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7 Appendix A

7.1 List of existing relevant standards in Europe

Standards on test methods and performance assessment of heat pumps and their components.

Standard	Title/content
EN 12900:2013	*Refrigerant compressors - Rating conditions, tolerances and presentation of manufacturer's performance data* Summary: This document specifies the rating conditions, tolerances and the method of presenting manufacturer's data for positive displacement refrigerant compressors. These include single stage compressors, single and two stage compressors using a means of fluid subcooling. This is required so that a comparison of different refrigerant compressors can be made. The data relate to the refrigerating capacity and power absorbed and include correction factors and part-load performance where applicable. This European Standard supersedes EN 12900:2005.
EN 13215:2017	*Condensing units for refrigeration - Rating conditions, tolerances and presentation of manufacturer's performance data* Summary: This European Standard specifies the rating conditions, tolerances and presentation of manufacturer's performance data for condensing units for refrigeration with compressors of the positive-displacement type. These include single stage compressors and single and two stage compressors having an integrated means of fluid sub cooling. This is required so that a comparison of different condensing units can be made. The data relate to the refrigerating capacity and power absorbed and include requirements for part-load performance where applicable.
EN 13771-1:2016	*Compressors and condensing units for refrigeration - Performance testing and test methods - Part 1: Refrigerant compressors* Summary: This European Standard specifies performance test methods for refrigerant compressors. These methods provide sufficiently accurate results for the determination of the refrigerating capacity, power absorbed, refrigerant mass flow, isentropic efficiency and the coefficient of performance. This European Standard applies only to performance tests where the equipment for testing is available.
EN 13771-2:2017	*Compressors and condensing units for refrigeration - Performance testing and test methods - Part 2: Condensing units* Summary: This European Standard applies only to condensing units for refrigeration and describes a number of selected performance test methods. These methods provide sufficiently accurate results for the determination of the refrigerating capacity, power absorbed, refrigerant mass flow and the coefficient of performance. This European Standard applies only to performance tests conducted at the manufacturer's works or wherever the instrumentation and load stability for testing to the accuracy required is available.

EN 1397:2015/AC:2016	*Heat exchangers - Hydronic room fan coil units - Test procedures for establishing the performance*
EN 14511-1:2018	*Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 1: Terms and definitions* Summary: This European Standard specifies the terms and definitions for the rating and performance of air conditioners, liquid chilling packages and heat pumps using either air, water or brine as heat transfer media, with electrically driven compressors when used for space heating and/or cooling. It also specifies the terms and definitions for the rating and performance of process chillers. This European Standard does not apply to heat pumps for domestic hot water, although certain definitions can be applied to these.
EN 14511-2:2018	*Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 2: Test conditions* Summary: 1.1 The scope of EN 14511 1 is applicable. 1.2 This European Standard specifies the test conditions for the rating of air conditioners, liquid chilling packages and heat pumps, using either, air, water or brine as heat transfer media, with electrically driven compressors when used for space heating and/or cooling. The standard also specifies the test conditions for the rating of air-cooled and water(brine)-cooled process chillers. 1.3 This European Standard specifies the conditions for which performance data is to be declared for single duct and double duct units for compliance to the Ecodesign Regulation 206/2012 and Energy Labelling Regulation 626/2011.
EN 14511-3:2018	*Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 3: Test methods* Summary: This European Standard specifies the test methods for the rating and performance of air conditioners, liquid chilling packages and heat pumps using either air, water or brine as heat transfer media, with electrically driven compressors when used for space heating and cooling. These test methods also apply for the rating and performance of process chillers. It also specifies the method of testing and reporting for heat recovery capacities, system reduced capacities and the capacity of individual indoor units of multisplit systems, where applicable.
EN 14511-4:2018	*Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 4: Requirements* Summary: 1.1 The scope of EN 14511 1 is applicable, with the exception of process chillers. 1.2 This European Standard specifies minimum operating requirements which ensure that air conditioners, heat pumps and liquid chilling packages using either air, water or brine as heat transfer media, with electrical driven compressors are

	fit for the use designated by the manufacturer when used for space heating and/or cooling.
EN 14825:2018	*Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance* Summary: This European Standard covers air conditioners, heat pumps and liquid chilling packages, including comfort and process chillers. It applies to factory made units defined in EN 14511-1, except single duct, double duct, control cabinet and close control units. It also covers direct expansion-to-water(brine) heat pumps (DX-to-water) as defined in EN 15879-1. This European Standard also covers hybrid heat pumps as defined in this standard. This European Standard gives the temperatures and part load conditions and the calculation methods for the determination of seasonal energy efficiency SEER and SEERon, seasonal space cooling energy efficiency $\eta_{s,c}$ seasonal coefficient of performance SCOP, SCOPon and SCOPnet, and seasonal space heating energy efficiency $\eta_{s,h}$ and seasonal energy performance ratio SEPR. Such calculation methods may be based on calculated or measured values. In case of measured values, this European Standard covers the test methods for determination of capacities, EER and COP values during active mode at part load conditions. It also covers test methods for electric power consumption during thermostat-off mode, standby mode, off-mode and crankcase heater mode.
EN 15218:2013	*Air conditioners and liquid chilling packages with evaporatively cooled condenser and with electrically driven compressors for space cooling - Terms, definitions, test conditions, test methods and requirements* Summary: This European Standard specifies the terms, definitions, test conditions, test methods and requirements for rating the performance of air conditioners and liquid chilling packages, with electrically driven compressors and with evaporatively cooled condenser when used for space cooling. The evaporatively cooled condenser is cooled by air and by the evaporation of external additional water. This additional external water is fed by a specific water supply circuit or by a water tank. This European Standard does not apply to air-to-air and air-to-water air conditioners with a condenser cooled by air and by the evaporation of water condensed on their evaporator. This European Standard applies to units equipped with a water tank or with a continuous water circuit supply that can also operate without water feeding. However the standard only concerns the testing of these units with water feeding. This European Standard applies to factory-made units which can be ducted. This European Standard applies to factory-made units of either fixed capacity or variable capacity by any means. Packaged units, single split and multisplit systems are covered by this European Standard. With regard to units consisting of several parts, this European Standard applies only to those designed and supplied as a complete package.

	Evaporatively cooled condenser units that can also operate in heating mode shall have their performance in this mode determined according to EN 14511. Installations used for industrial processes cooling are not within the scope of this European Standard. This European Standard specifies the conditions for which performance data shall be declared for compliance to the Ecodesign regulation 206/2012 and to the Energy Labelling regulation 626/2011 of air conditioners with evaporatively cooled condenser in cooling mode.
EN 15879-1:2011	*Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling - Part 1: Direct exchange-to-water heat pumps* <u>Summary:</u> This European Standard specifies the terms and definitions, test conditions, test procedures and requirements for the rating and performance of direct exchange-to-water ground coupled heat pumps with electrically driven compressors, used for space heating and/or cooling. Brine can be used instead of water. This European Standard applies to factory-made units with horizontal in-ground collectors. In the case of units consisting of several parts, this standard applies only to those designed and supplied as a complete package. Water-to-direct exchange and direct-exchange-to-direct exchange ground coupled heat pumps are covered by EN 15879-2. Direct exchange-to-air ground coupled heat pumps and air-to-direct exchange heat pumps are covered by EN 15879-3. This European Standard does not apply to units using transcritical cycles, e.g. with CO_2 as refrigerant.
EN 16147:2017/AC:2017	*Heat pumps with electrically driven compressors - Testing, performance rating and requirements for marking of domestic hot water units*
CEN ISO/TS 16491:2012	*Guidelines for the evaluation of uncertainty of measurement in air conditioner and heat pump cooling and heating capacity tests (ISO/TS 16491:2012)* <u>Summary:</u> ISO/TS 16491:2012 gives guidance on the practical applications of the principles of performance measurement of air-cooled air-conditioners and air-to-air heat pumps as described in ISO 5151, ISO 13253, and ISO 15042.
EN 810:1997	*Dehumidifiers with electrically driven compressors - Rating tests, marking, operational requirements and technical data sheet* <u>Summary:</u> This standard specifies the methods for testing and reporting the rating and operational requirements and it specifies requirements for marking for dehumidifiers with electrically driven compressors. This standard does not apply to continuously variable capacity control units. In the case of dehumidifiers consisting of several parts, the standard applies only to those designed and supplied as a complete package.

As part of the performance of the heat pump, standards on the determination of the sound level are listed below.

Standard	**Title/content**

EN 12102-1:2017	*Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers* Summary: This European Standard establishes requirements for determining, in accordance with a standardized procedure, the sound power level emitted into the surrounding air by air conditioners, heat pumps, liquid chilling packages with electrically driven compressors when used for space heating and/or cooling, and/or for process, as described in the EN 14511 series and dehumidifiers as described in EN 810. This European Standard also covers the measurement of the sound power level of evaporatively cooled condenser air conditioners, as defined in EN 15218. However, the measurement will be done without external water feeding and these units will thus be considered as the other air conditioners covered by the EN 14511 series. It is emphasized that this measurement standard only refers to airborne noise.
EN 12102-2:2019	*Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 2: Heat pump water heaters* Summary: This document specifies methods for testing the sound power level of air/water, brine/water, water/water and direct exchange/water heat pump water heaters and heat pump combination heaters with electrically driven compressors and connected to or including a domestic hot water storage tank for domestic hot water production. This European Standard comprises only the testing procedure for the domestic hot water production of the heat pump system. NOTE 1 Testing procedures for simultaneous operation for domestic hot water production and space heating are not treated in this standard. Simultaneous operation means that domestic hot water production and space heating generation occur at the same time and may interact. NOTE 2 For space heating function, the requirements are given in EN 12102-1:2017. This European Standard only applies to water heaters which are supplied in a package of heat pump and storage tank. In the case of water heaters consisting of several parts with refrigerant connections, this European Standard applies only to those designed and supplied as a complete package. This European Standard does not specify requirements for the quality of the used water.
EN 16583:2015	*Heat exchangers - Hydronic room fan coils units - Determination of the sound power level* Summary: This European Standard applies to hydronic fan coil units (FCU) as factory-made single assemblies which provide the functions of cooling and/or heating but do not include the source of cooling or heating. The standard covers both air free delivery and air ducted units with a maximum external static pressure due to duct resistance of 120 Pa max.

	This European Standard provides methods for the determination of the acoustical performance of fan coil units, defining standard working condition and installation. It is not the purpose of this standard to specify the tests used for production or field testing.

Other regulations related with the performance/efficiency of the heat pump (Ecolabel/Ecodesign) because they affect the design process and therefore the HP behavior:

Regulation	**Description**
1253/2014	COMMISSION REGULATION (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units
206/2012	COMMISSION REGULATION (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans
813/2013	COMMISSION REGULATION (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters
2014/C207/02	Commission communication in the framework of the implementation of Commission Regulation (EU) No 813/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters and of Commission Delegated Regulation (EU) No 811/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device (2014/C 207/02)
814/2013	COMMISSION REGULATION (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks
2014/C207/03	Commission communication in the framework of the implementation of Commission Regulation (EU) No 814/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks and of Commission Delegated Regulation (EU) No 812/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device (2014/C 207/03)
2014/1254	COMMISSION DELEGATED REGULATION (EU) No 1254/2014 of 11 July 2014 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of residential ventilation units
2011/626	COMMISSION DELEGATED REGULATION (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners
2013/811	COMMISSION DELEGATED REGULATION (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters,

	packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device
2014/C207/02	Commission communication in the framework of the implementation of Commission Regulation (EU) No 813/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters and of Commission Delegated Regulation (EU) No 811/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device
2013/812	COMMISSION DELEGATED REGULATION (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device
2014/C207/03	Commission communication in the framework of the implementation of Commission Regulation (EU) No 814/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks and of Commission Delegated Regulation (EU) No 812/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device (2014/C 207/03)

In the following other standards relevant to the CCB concept are listed, they refer to other components of the CCB, rather than the heat pump, or they are linked to the CCB application (e.g. buildings energy performance; automation in buildings).

Standard	**Title/content**
EN 12977-3:2018	*Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores* Summary: This European Standard specifies test methods for the performance characterization of stores which are intended for use in small custom built systems as specified in EN 12977-1. Stores tested according to this document are commonly used in solar hot water systems. However, the thermal performance of all other thermal stores with water as a storage medium can also be assessed according to the test methods specified in this document. The document applies to stores with a nominal volume between 50 l and 3 000 l. This document does not apply to combistores. Performance test methods for solar combistores are specified in EN 12977-4.
EN 12977-4:2018	*Thermal solar systems and components - Custom built systems - Part 4: Part 4: Performance test methods for solar combistores* Summary: This European Standard specifies test methods for the performance characterization of stores which are intended for use in small custom built systems as specified in EN 12977-1. Stores tested according to this document are

	commonly used in solar combisystems. However, the thermal performance of all other thermal stores with water as a storage medium (e.g. for heat pump systems) can be also assessed according to the test methods specified in this document. This document applies to combistores with a nominal volume up to 3 000 l and without integrated burner. NOTE This document is extensively based on references to EN 12977-3:2012.
UNI EN 12897:2016	*Water supply. Specification for indirectly heated unvented (closed) storage water heaters* Summary: This European Standard specifies the constructional and performance requirements and methods of test for indirectly heated, unvented (closed) storage water heaters of up to 2 000 l volume suitable for connection to a water supply at a pressure between 0,05 MPa and 1,0 MPa (0,5 bar and 10 bar), and fitted with control and safety devices designed to prevent the temperature of the stored drinking water from reaching 95 °C. Whilst storage water heaters intended primarily for direct heating are not covered by this standard, it does allow the provision of electric heating elements for auxiliary use.
EN 50440:2015	*Efficiency of domestic electrical storage water heaters and testing methods* Summary: This European Standard specifies methods for measuring the performance of electric storage water heaters for the production of sanitary hot water for household and similar use. The object is to state and define the principal performance characteristics of electric storage water heaters and to describe the test methods for measuring these characteristics. NOTE 1 This standard does not apply to; ? storage water heaters that use electricity as a secondary source of heating the water; ? storage water heaters that do not use a tank to storage hot water; ? electric storage water heaters that do not meet the minimum (or maximum) output performance of the smallest (or biggest) load profile, as defined in Table 4. NOTE 2 This standard does not specify performance or safety requirements. For safety requirements see EN 60335-1 in conjunction with EN 60335-2-21.
EN 15332:2020	*Heating boilers - Energy assessment of hot water storage tanks* Summary: This document specifies a method for the energy assessment of domestic/sanitary hot water storage tanks of up to 2 000 l. Whilst this document does not cover water heaters intended primarily for direct heating, it does allow the provision of electric heating elements for auxiliary use. Primary heating buffer tanks are not covered by this document. Heat losses of domestic hot water storage tanks integrated into combi boilers marketed as a single unit are not covered by this document.
EN 15316-4-2:2017	*Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2* Summary: This European Standard covers heat pumps for space heating, heat pump water heaters (HPWH) and heat pumps with combined space heating and domestic hot water production in alternate or simultaneous operation, where the same heat

	pump delivers the heat to cover the space heating and domestic hot water heat requirement. The standard provides a calculation method under steady conditions that corresponds to one calculation step. The results of this calculation are incorporated in larger building models and take in account the influence of the external conditions and building control that influence the energy requirements for heating supplied by the heat pump system. The scope of this part is to standardize the: - required inputs; - calculation methods; - required outputs Generation for space heating and domestic hot water production of the following heat pump systems, including control of: - electrically-driven vapour compression cycle (VCC) heat pumps; - combustion engine-driven vapour compression cycle heat pumps; - thermally-driven vapour absorption cycle (VAC) heat pumps, using combinations of heat source and heat distribution listed in Table 1. This standard does not cover sizing or inspection of heat pumps. This standard deals with heat generators for heating or for combined domestic hot water and heating service. Generators for domestic hot water only are taken into account into module M8-8. NOTE 1 Heat pumps for cooling systems are taken into account into module M4-8. NOTE 2 Heat pumps for space heating using air (distribution) are taken into account in module M5-8. Other generation systems such as boilers are covered in other sub modules of part M3-8. This is the revision of EN 15316 4 2:2008. The revision covers the adaptation of the standard to hourly and monthly energy calculation. Table 2 shows the relative position of this standard within the set of EPB standards in the context of the modular structure as set out in prEN ISO 52000 1. NOTE 1 In prCEN ISO/TR 52000 2 the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation. NOTE 2 The modules represent EPB standards, although one EPB standard may cover more than one module and one module may be covered by more than one EPB standard, for instance a simplified and a detailed method respectively. See also Clause 2 and Tables A.1 and B.1.
EN 15316-5:2018	*Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 5: space heating and DHW storage systems (not cooling), module M3-7, M8-7* <u>Summary:</u> This European Standard covers energy performance calculation of water based storage sub-systems used for heating, for domestic hot water or for combination of these. This standard does not cover sizing or inspection of such storage systems.

	Table 1 shows the relative position of this standard within the set of EPB standards in the context of the modular structure as set out in EN ISO 52000-1. NOTE 1 In CEN ISO/TR 52000 2 the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation. NOTE 2 The modules represent EPB standards, although one EPB standard may cover more than one module and one module may be covered by more than one EPB standard, for instance a simplified and a detailed method respectively. See also Clause 2 and Tables A.1 and B.1.
EN 15232-1:2017	*Energy performance of buildings - Part 1: Impact of Building Automation, Controls and Building Management - Modules M10-4,5,6,7,8,9,10* Summary: This European Standard specifies: - a structured list of control, building automation and technical building management functions which contribute to the energy performance of buildings; functions have been categorized and structured according to building disciplines and so called Building automation and control (BAC); - a method to define minimum requirements or any specification regarding the control, building automation and technical building management functions contributing to energy efficiency of a building to be implemented in building of different complexities; - a factor based method to get a first estimation of the effect of these functions on typical buildings types and use profiles; - detailed methods to assess the effect of these functions on a given building.

Eventually some standards related to the concept of passive house are reported below:

Title/content
Requirements and testing procedures for energetic and acoustical assessment of Passive House ventilation systems < 600 m3/h for Certification as Passive House suitable components
Requirements and testing procedures for energetic and acoustical assessment of Passive House (facade integrated) ventilation systems
Certificate criteria for the energy and acoustic assessment of compact heat pump units for certification as "Certified Passive House Components"
Requirements and testing conditions for energy efficiency, comfort, acoustic and hygienic assessment of air-to-air heat pumps for Certification as Passive House suitable components
Testing conditions for energy efficiency, comfort, acoustic and hygienic assessment of Ventilation unit equipped with heat pump including domestic hot water preparation for Certification as Passive House suitable components
Testing procedure for the energy and acoustic assessment of compact heat pump units for certification as Passive House suitable components
Certificate criteria for the energy and acoustic assessment of compact heat pump units for certification as "Certified Passive House Components"
Requirements and testing conditions for energy efficiency, comfort, acoustic and hygienic assessment of air-to-air heat pumps for Certification as Passive House suitable components

7.2 List of existing relevant standards in Canada

The standards available in Canada to test the performance of variable capacity heat pumps or heat pumps connected to a storage (i.e. water heater) are listed below. They do not include the peculiar aspects of a CCB.

Standard	Title/content
CSA EXP07	*Test Standard for Variable Capacity (Air-Air) Heat Pumps* Summary CSA EXP07 is a new dynamic load based test procedure designed to better represent the performance of variable capacity air to air heat pumps in Canada. The basic concept involves testing the heat pump according to a "Load Line", which is designed to capture both the maximum capacity, and the ability of the heat pump to modulate at milder conditions and lower imposed loads. Heat pump operations follow the units built in controls, while the difference between the load line and measured capacity is used to apply a rate of change to the room temperature setpoint to allow the unit to follow the load (Sager, 2020). One of the main benefits of this type of testing is that it directly includes the impact of cycling and defrost cycles on system COPs, providing a more realistic depiction of system performance in Canadian buildings. The new performance rating also proposes that seasonal COPs are provided for five different climate zones in Canada, as opposed to the single climate zone currently used in HSPF calculations.
CSA EXP10	*Test Standard for Heat Pump Water Heater* Summary An initiative currently under development, CSA EXP10 seeks to develop a performance rating and test procedure for air-source heat pump water heaters. This could be of particular interest to the Annex as it will couple the heat pump with storage (albeit hydronic sensible storage).

7.3 List of existing relevant standards in US

A number of standards exist in the United States for systems/components that are related to the CCB concept (heat pumps and air conditioning, water tanks, and thermal storage systems). These include both test methods and requirements for performance, efficiency, noise, and safety. This document provides information on relevant standards identified among the most common HVAC industry organizations that develop standards [American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) and Air-Conditioning, Heating, and Refrigeration Institute (AHRI)] and the United States Department of Energy (US DOE) for the efficiency standards.

Test standards:

a. ANSI/ASHRAE Test Standards:

Note: ANSI/ASHRAE test standards are available for purchase from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 1791 Tullie Circle NE, Atlanta GA 30329. https://www.ashrae.org/technical-resources/standards-and-guidelines/. The purpose and scope of all ASHRAE's standards and guidelines are available without charge: https://www.ashrae.org/technical-resources/standards-and-guidelines/titles-purposes-and-scopes/.

Standard	Title/content
ANSI/ASHRAE Standard 37-2009R	*Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment* (Note: revision in process that will combine 37 and 116) Summary Purpose: This standard provides test methods and calculations for steady-state, cyclic, and part-load performance and methods for establishing seasonal performance for unitary air-conditioning and heat pump equipment, including single capacity, multiple capacity, variable capacity, unloading, or multiple compressors for ducted and ductless systems. Scope: This standard applies to electrically driven mechanical-compression unitary air conditioners and heat pumps consisting of one or more assemblies that include an indoor air coil(s), a compressor(s), and an outdoor coil(s). Where such equipment is provided in more than one assembly, the separated assemblies are designed to be used together.
ANSI/ASHRAE Standard 116-2010	*Methods of Testing for Rating Seasonal Efficiency of Unitary Air Conditioners and Heat Pumps*, (Note: will be combined with 37) Summary Purpose: This standard provides test methods and calculational procedures for determining the capacities and cooling seasonal efficiency ratios for unitary air conditioning and heat pump equipment and heating seasonal performance factors for heat pump equipment. Scope: This standard covers electrically driven, air-cooled air conditioners and heat pumps used in residential applications with cooling capacity of 65,000 Btu/h and less or in the case of heating only heat pumps, heating capacity of 65,000 Btu/h and less-
ANSI/ASHRAE Standard 40-2014	*Methods of Testing for Rating Heat Operated Unitary Air-Conditioning and Heat Pump Equipment* Summary Purpose: This standard provides test methods for determining the heating and cooling output capacities and energy inputs of unitary air-conditioning and heat pump equipment that is heat-operated (see Section 3, “Definitions”). Scope: This standard applies to heat-operated unitary air conditioners and heat pumps consisting of one or more assemblies, including engine-driven systems. Where such equipment is provided in more than one assembly, the separate assemblies are designed to be used together.
ANSI/ASHRAE Standard 58-1986 (RA 2014)	*Methods of Testing for Rating Room Air Conditioner and Packaged Terminal Air Conditioner Heating Capacity* Summary Purpose: The purpose of this standard is to prescribe test methods for determining the heating capacities and air flow quantities for room air conditioners and packaged terminal air conditioners equipped with means for room heating. Scope: This standard: (a) establishes a uniform method of testing for obtaining rating data, (b) specifies test equipment for performing such tests, (c) specifies data required and calculations to be used, and (d) lists and defines the terms used in testing.
ANSI/ASHRAE Standard 94.1-2010	*Method of Testing Active Latent-Heat Storage Devices Based on Thermal Performance, (withdrawn but available for purchase)*

	Summary Purpose: The purpose of this standard is to provide a standard procedure for determining the thermal performance of latent heat thermal energy storage devices used in heating, air-conditioning, and service hot water systems. Scope: This standard applies to latent heat thermal energy storage devices in which a transfer fluid enters the device through a single inlet and leaves the device through a single outlet.
ANSI/ASHRAE Standard 94.2-2010	*Method of Testing Thermal Storage Devices with Electrical Input and Thermal Output Based on Thermal Performance, (withdrawn but available for purchase)* Summary Purpose: The purpose of this standard is to provide a standard procedure for determining the energy performance of electrically charged thermal energy storage devices used in heating systems. Scope: This standard applies to thermal storage devices that are charged electrically and discharged thermally. The energy may be stored as latent heat or as sensible heat or as a combination of the two.
ANSI/ASHRAE Standard 94.3-2010	*Method of Testing Active Sensible Thermal Energy Devices Based on Thermal Performance, (withdrawn but available for purchase)* Summary Purpose: The purpose of this standard is to provide a standard procedure for determining the thermal performance of sensible thermal energy storage devices used in heating, air-conditioning, and service hot water systems. Scope: This standard applies to sensible-heat-type thermal energy storage devices in which a transfer fluid enters the device through a single inlet and leaves the device through a single outlet. Storage devices having more than one inlet and/or outlet may be tested according to this standard, but each flow configuration involving a single inlet and single outlet must be tested separately.
ANSI/ASHRAE Standard 118.1-2012R	*Method of Testing for Rating Commercial Gas, Electric and Oil Service Water Heating Equipment*, (revision in process) Summary Purpose: The purpose of this standard is to provide test procedures for rating directly heated commercial-service water-heating equipment. Scope: This standard provides test procedures for determining the efficiency and hot-water delivery capability of the water-heating equipment to which it applies. This standard applies to electric resistance, heat pump, natural and propane gas-fired, and oil-fired water-heating equipment, including hot-water supply boilers, with input ratings less than 12,500,000 Btu/h (3660 kW).
ANSI/ASHRAE Standard 118.2-2006R	*Method of Testing for Rating Residential Water Heaters*, (revision in process) Summary Purpose: The purpose of this standard is to provide test procedures for rating the efficiency and hot water delivery capabilities of directly heated residential water heaters and residential-duty commercial water heaters. Scope: This standard applies to the following: a. Electric heat pump storage water heaters that: use electricity as the energy source, have a nameplate input rating of 12 kW (40,956 Btu/h) or less, have a rated storage capacity of 120 gallons (450 liters) or less, are designed to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water, and are designed to heat and store water at a

	thermostatically-controlled temperature less than or equal to 180 °F (82 °C). b. Electric instantaneous water heaters that: use electricity as the energy source, have a nameplate input rating of 58.6 kW (200,000 Btu/h) or less, contain no more than one gallon of water per 4,000 Btu per hour of input, and are designed to provide outlet water at a controlled temperature less than or equal to 180 °F (82 °C). c. Electric storage water heaters that: use electricity as the energy source, have a nameplate input rating of 12 kW (40,956 Btu/h) or less, have a rated storage capacity of 120 gallons (450 litres) or less, contain more than one gallon of water per 4,000 Btu per hour of input, and may be designed to heat and store water at a thermostatically-controlled temperature less than or equal to 180 °F (82 °C). d. Gas-fired heat pump storage water heaters that: use gas as the main energy source, have a nameplate input rating of 20,000 Btu/h (26.4 MJ/h) or less, have a maximum current rating of 24 amperes (including all auxiliary equipment such as fans, pumps, controls, and, if on the same circuit, any resistive elements) at an input voltage of no greater than 250 volts, have a rated storage volume not more than 120 gallons (450 litres), and are designed to transfer thermal energy from one temperature level to a higher temperature level to deliver water at a thermostatically controlled temperature less than or equal to 180 °F (82 °C). e. Gas-fired instantaneous water heaters that: use gas as the main energy source, have a nameplate input rating less than 200,000 Btu/h (210 MJ/h), contain no more than one gallon of water per 4,000 Btu per hour of input, and are designed to provide outlet water at a controlled temperature less than or equal to 180 °F (82 °C). f. Gas-fired storage water heaters that: use gas as the main energy source, have a nameplate input rating of 105,000 Btu/h (110 MJ/h) or less, have a rated storage capacity of 120 gallons (450 litres) or less, contain more than one gallon of water per 4,000 Btu per hour of input, and are designed to heat and store water at a thermostatically-controlled temperature less than or equal to 180 °F (82 °C). g. Oil-fired instantaneous water heaters that: use oil as the main energy source, have a nameplate input rating of 210,000 Btu/h (220 MJ/h) or less, contain no more than one gallon of water per 4,000 Btu per hour of input, and are designed to provide outlet water at a controlled temperature less than or equal to 180 °F (82 °C). The unit may use a fixed or variable burner input. h. Oil-fired storage water heaters that: use oil as the main energy source, have a nameplate input rating of 140,000 Btu/h (148 MJ/h) or less, have a rated storage capacity of 120 gallons (450 litres) or less, contain more than one gallon of water per 4,000 Btu per hour of input, and are designed to heat and store water at a thermostatically-controlled temperature less than or equal to 180 °F (82 °C).
ANSI/ASHRAE Standard 137-2013 (RA2017)	*Methods of Testing for Efficiency of Space Conditioning/Water-Heating Appliances that Include a Desuperheater Water Heater* <u>Summary</u> <u>Purpose</u>: This standard provides test methods and calculation procedures for establishing the efficiencies of space-conditioning/water-heating appliances having refrigerant-to-water desuperheaters.

	Scope: This standard covers electric, air-to-air, space-conditioning appliances that include a refrigerant-to-water desuperheater and have rated cooling capacities of less than 65,000 Btu/h.
ANSI/ASHRAE Standard 150-2010	*Method of Testing the Performance of Cool Storage Systems* Summary Purpose: This standard prescribes a uniform set of testing procedures for determining the cooling capacities and efficiencies of cool storage systems. Scope: This standard covers cool storage systems composed of chillers, storage medium, storage device or vessel, heat sink equipment or heat sink systems, and other auxiliary equipment required to provide a complete and working system.
ANSI/ASHRAE Standard 194-2017	*Method of Testing for Direct-Expansion Ground Source Heat Pumps* Summary Purpose: The purpose of this standard is to provide a method of test to determine capacity and efficiency of direct-expansion ground source heat pumps. Scope: This standard applies to factory-assembled unitary heat pumps (that utilize indoor air as energy sink on heating and the energy source on cooling and a refrigerant as the heat transfer medium in the ground) and are used for direct-expansion (DX) ground source systems.
ANSI/ASHRAE Standard 206-2013 (RA 2017)	*Methods of Testing for Rating of Multipurpose Heat Pumps for Residential Space Conditioning and Water Heating* Summary Purpose: The purpose of this standard is to establish definitions, classifications and test requirements for the determination of the efficiency of multi-purpose, space conditioning and water heating equipment. Scope: This standard applies to electrically powered unitary heat pump equipment that provides both space conditioning and water heating functions, or that combines space conditioning and water heating with other functions, such as dehumidification and/or ventilation. The equipment to which this standard applies has the capability to heat water without requiring the simultaneous performance of space conditioning. It addresses air-source, water-source, ground water-source, ground-source closed loop, and direct geoexchange equipment. It applies to air-source equipment rated below 65,000 Btu/h [19,000 W], and water-source, ground water-source, ground-source closed loop, and direct geoexchange equipment rated below 135,000 Btu/h [40,000 W].
ANSI/ASHRAE Standard 212-2019	*Method of Test for Determining Energy Performance and Water-Use Efficiency of Add-On Evaporative Pre-Coolers for Unitary Air Conditioning Equipment* Summary Purpose: To provide test methods for gathering performance data for use in calculating the design and seasonal energy savings potential and water-use performance of add-on evaporative pre-coolers for condenser inlet air of air-cooled, direct expansion unitary air conditioning equipment. Scope: This standard applies to add-on evaporative pre-cooling accessories applied to the condenser inlet air of air-cooled unitary direct-expansion cooling equipment with less than or equal to 240 KBtuh cooling capacity.

Proposed ASHRAE Standard 221P	*Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System, (under development)* Summary Purpose: The purpose of this standard is to prescribe a field evaluation and test method to measure and score the performance, in terms of delivered cooling or heating capacity, or cooling efficiency, of an installed unitary HVAC system. Scope: This standard: Defines performance scoring methods for cooling and heating system delivered capacity and cooling system efficiency; Establishes uniform methods of measurements and testing procedures for airflow, temperature, enthalpy, and power; Specifies test instruments, specifications and calibration requirements for performing such measurements and tests; Specifies data required and calculations to be used; and Applies to single-zone unitary split and packaged direct expansion (DX) cooling, air-source heat pump, and combustion furnace HVAC systems of any capacity, and with forced-air distribution systems.
ASHRAE/ANSI/AHRI/ISO Standard 13256-1:1998 (RA 2012)	*Water-source heat pumps - testing and rating for performance - Part 1: Water-to-air and brine-to-air heat pumps* Summary Purpose: This part of ISO 13256 covers heating and cooling systems which are generally referred to as "water-source heat pumps." These systems generally include an indoor coil with air-moving means, a compressor, and a refrigerant-to-water or refrigerant-to-brine heat exchanger. A system may provide both heating and cooling, cooling-only, or heating-only functions. Scope: This part of ISO 13256 establishes performance testing and rating criteria for factory-made residential, commercial and industrial, electrically-driven, mechanical-compression type, water-to-air and brine-to-air heat pumps. The requirements for testing and rating contained in this part of ISO 13256 are based on the use of matched assemblies.
ASHRAE/ANSI/AHRI/ISO Standard 13256-2:2012	*Water-source heat pumps - testing and rating for performance - Part 2: Water-to-water and brine-to-water heat pumps* Summary Purpose: This part of ISO 13256 covers heating and cooling systems which are generally referred to as "water-source heat pumps." These systems generally include an indoor coil with air-moving means, a compressor, and a refrigerant-to-water or refrigerant-to-brine heat exchanger. A system may provide both heating and cooling, cooling-only, or heating-only functions. Scope: This part of ISO 13256 establishes performance testing and rating criteria for factory-made residential, commercial and industrial, electrically driven, mechanical-compression type, water-to-water and brine-to-water heat pumps. The requirements for testing and rating contained in this part of ISO 13256 are based on the use of matched assemblies.

b. AHRI Test standards

Note: The AHRI test standards are available for free download from Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A. http://www.ahrinet.org/search-standards.

Standard	Title/content
AHRI Standard 210/240 (2017)	*Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment* Summary Purpose: The purpose of this standard is to establish the following for Unitary Air-conditioners and Unitary Air-source Heat Pumps: definitions, classifications, test requirements, rating requirements, operating requirements, minimum data requirements for Published Ratings, marking and nameplate data, and conformance conditions Scope: This standard applies to factory-made Unitary Air-conditioners and Unitary Air-source Heat Pumps with capacities less than 65,000 Btu/h as defined in Section 3.
AHRI Standard 290 (1996)	*Air-Conditioning and Heat Pump Equipment Incorporating Refrigerant to Potable Water Heating Devices*, (WITHDRAWN) Summary Purpose: Applicable to factory assembled air conditioners and heat pumps or matched assemblies detailed in 3.2, 3.12 and 3.18. incorporate factory or field supplied refrigerant to potable water heating devices. Applicable to all ratings of the air conditioner or heat pump when used in combination with a heating device. Applicable to air source, electrically driven, mechanical compression type systems rated less than 65,000 Btu/h 19,000 W as detailed in ARI 210/240. Not applicable to testing and rating individual condensing units, coils or water heating devices for separate use.
AHRI Standard 310/380 (2017)	*Packaged Terminal Air-conditioners & Heat Pumps* Summary Purpose: The purpose of this Standard is to establish the following for packaged terminal air-conditioner and heat pump equipment: a) test requirements; b) rating requirements; c) minimum data requirements for published ratings; d) operating requirements; e) marking and nameplate data; and f) conformance conditions. Scope: This Standard applies to factory-manufactured residential, commercial, and industrial packaged terminal air-conditioners and heat pumps as defined in Clause 3. This Standard applies to electrically operated vapour-compression refrigeration systems. This standard applies to packaged terminal air-conditioners and heat pumps intended for unducted installation, but may be employed with ductwork having external static resistance up to 25 Pa (0.1 in H2O).
AHRI Standard 340/360 (IP/2019)	*Performance Rating of Commercial and Industrial Air-conditioning & Heat Pump Equipment* Summary Purpose: The purpose of this standard is to establish for Commercial and Industrial Unitary Air-conditioning and Heat Pump Equipment: definitions; classifications; test requirements; rating requirements; minimum data requirements for Published Ratings; operating requirements; marking and nameplate data; and conformance conditions.
AHRI Standard 550/590 (IP) & 551/591 (SI) (2018)	*Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle* (with Errata) Summary

	Purpose: The purpose of this standard is to establish for Water-chilling and Heat Pump Water-heating Packages using the vapor compression cycle: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; conversions and calculations; nomenclature; and conformance conditions. Scope: This standard applies to factory-made vapor compression refrigeration Water-chilling and Water-heating Packages including one or more compressors. These Water-chilling and Water-heating Packages include: Water-cooled, Air-cooled, or Evaporatively-cooled Condensers; Water-cooled heat recovery condensers; Air-to-water heat pumps; and Water-to-water heat pumps with a capacity greater or equal to 135,000 Btu/h.
AHRI Standard 870(IP) & 871(SI) (2016)	*Performance Rating of Direct GeoExchange Heat Pumps* Summary Purpose: The purpose of this standard is to establish for Direct Geoexchange Heat Pumps: definitions; classification; test and rating requirements; minimum data requirements for Published Ratings; operating requirements; marking and nameplate data; and conformance conditions. For the remainder of this standard, the terms "heat pump" or "equipment" are also used to designate Direct Geoexchange Heat Pumps. Scope: This standard applies to factory made residential, commercial and industrial Direct Geoexchange Heat Pumps as defined in Section 3, and within the capacity range of 5,270 W through 52,700 W.
AHRI Standard 1380(IP) (2019)	*Demand Response through Variable Capacity HVAC Systems in Residential and Small Commercial Applications* Summary Purpose: The purpose of this standard is to establish for Demand Response (DR) through variable capacity HVAC systems in residential and small commercial applications definitions; test requirements, operating and physical requirements, minimum data requirements for published ratings, marking and nameplate data and conformance conditions. Scope: This Standard applies to communication, infrastructure and system functionality as they relate to the implementation of energy management strategies for variable capacity DR-ready HVAC systems installed in residential and small commercial applications with capacities of 65,000 Btu/hr or less as defined in Section 3.

c. DOE Efficiency Standards

Standard	**Title/content**
82 FR 1786	*Energy Conservation Program: Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps* Summary The Energy Policy and Conservation Act of 1975 (EPCA), as amended, prescribes energy conservation standards for various consumer products and certain commercial and industrial equipment, including residential central air conditioners and heat pumps. EPCA also requires the U.S. Department of Energy (DOE) to periodically determine whether more-stringent, amended standards would be technologically feasible and economically justified, and

	would save a significant amount of energy. In this direct final rule, DOE adopts amended energy conservation standards for residential central air conditioners and heat pumps.
81 FR 2420	*Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards for Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces* Summary The Energy Policy and Conservation Act of 1975, as amended (EPCA), prescribes energy conservation standards for various consumer products and certain commercial and industrial equipment, including small, large, and very large air-cooled commercial package air conditioning and heating equipment and commercial warm air furnaces. EPCA also requires that the U.S. Department of Energy (DOE) periodically review and consider amending its standards for specified categories of industrial equipment, including commercial heating and air conditioning equipment, in order to determine whether more- stringent, amended standards would be technologically feasible and economically justified, and save a significant additional amount of energy. In this direct final rule, DOE is amending the energy conservation standards for both small, large, and very large air-cooled commercial package air conditioning and heating equipment and commercial warm air furnaces after determining that the amended energy conservation standards being adopted for these equipment would result in the significant conservation of energy and be technologically feasible and economically justified.
75 FR 20112	*Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* Summary The U.S. Department of Energy (DOE) is amending the existing energy conservation standards for residential water heaters (other than tabletop and electric instantaneous models), gas-fired direct heating equipment, and gas-fired pool heaters. It has determined that the amended energy conservation standards for these products would result in significant conservation of energy, and are technologically feasible and economically justified.
80 FR 42614	*Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards and Test Procedures for Commercial Heating, Air-Conditioning, and Water-Heating Equipment* Summary The U.S. Department of Energy (DOE) is amending its energy conservation standards for small three-phase commercial air-cooled air conditioners (single package only) and heat pumps (single package and split system) less than 65,000 Btu/h; water-source heat pumps; and commercial oil-fired storage water heaters. Pursuant to the Energy Policy and Conservation Act of 1975 (EPCA), as amended, DOE must assess whether the uniform national standards for these covered equipment need to be updated each time the corresponding industry standard--the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)/ Illuminating Engineering Society of North America (IESNA) Standard 90.1 (ASHRAE Standard 90.1)--is amended, which most recently occurred on

	October 9, 2013. Under EPCA, DOE may only adopt more stringent standards if there is clear and convincing evidence showing that more stringent amended standards would be technologically feasible and economically justified, and would save a significant additional amount of energy. The levels DOE is adopting are the same as the efficiency levels specified in ASHRAE Standard 90.1-2013. DOE has determined that the ASHRAE Standard 90.1-2013 efficiency levels for the equipment types listed above are more stringent than existing Federal energy conservation standards and will result in economic and energy savings compared existing energy conservation standards. Furthermore, DOE has concluded that clear and convincing evidence does not exist that would justify more-stringent standard levels than the efficiency levels in ASHRAE Standard 90.1-2013 for any of the equipment classes. DOE has also determined that the standards for small three-phase commercial air-cooled air conditioners (split system) do not need to be amended. DOE is also updating the current Federal test procedure for commercial warm-air furnaces to incorporate by reference the most current version of the American National Standards Institute (ANSI) Z21.47, Gas-fired central furnaces, specified in ASHRAE Standard 90.1, and the most current version of ASHRAE 103, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.

7.4 List of existing relevant standards in China

Standards in place in China about heat pumps and storage systems.

Standard	Title/content
GB/T 18837-2015	*Multi-connected air-conditioning(heat pump)unit* Summary This standard specifies the terms and definitions, types, models, and basic parameters, requirements, tests, inspection rules, marking, packaging, transportation and storage of multi-connected air conditioning (heat pump) units (hereinafter referred to as "units"). This standard applies to multi-type air conditioning (heat pump) units using Class A1 refrigerants specified in GB/T 7778. Units using A2L refrigerants and double refrigeration cycle and multi-refrigeration cycle can refer to this standard.
GB/T 18836-2017	*Ducted air-conditioning (heat pump) units* Summary This standard specifies the terms and definitions, types and basic parameters, requirements, tests, inspection rules, marking, packaging, transportation and storage of air duct (air pump) units (hereinafter referred to as "air conditioners"). This standard applies to duct air supply (heat pump) unit.
GB/T 19409-2013	*Water-source(ground-source) heat pump* Summary This standard specifies the water (ground) source heat pump (hereinafter referred to as "units") of the terms and definitions, types and basic parameters, requirements, test methods, inspection rules, marking, packaging, transport and storage.
GB 30721-2014	*Minimum allowable values of energy efficiency and energy efficiency grades for water-source (ground-source) heat pumps*

	Summary This Standard specifies the minimum allowable values of energy efficiency, evaluation values of energy conservation, energy efficiency grades, test methods, and inspection rules for water-source (ground-source) heat pumps. This Standard applies to the water-source (ground-source) heat pumps of household, commercial and industrial uses, and other similar uses that use electrical and mechanical compression systems and use water as cold (hot) source.
GB 50366-2020	*Technical code for ground-source heat pump system*
GB/T 26973-2011	*Specification of solar water heating systems assisted with air-source heat pump (for capacity of water tank more than 0.6 m^3)* Summary This standard specifies the air source heat pump and solar hot water system definitions, symbols and units, composition and classification, design requirements, technical requirements, test methods, construction and installation requirements, commissioning and acceptance, file innovations of other technical specifications. This standard applies to the use of air pushed heat pump solar water heating system (tank volume greater than 0. 6 m^3).
GB/T 31512-2015	*Economic operation of water-source heat pump systems* Summary This Standard specifies the basic requirements for water source heat pump system of economic operation, evaluation and methods, test methods and management measures. This Standard applies to water as cold (hot) source of household, commercial and industrial use and similar uses electro-mechanical compression type water source heat pump systems.
JB/T 11966-2014	*Air-source multiple split air-conditioning(heat pump) and water heating unit* Summary This Standard specifies the terms and definitions air source multi air conditioning (heat pump) hot water units, types and basic parameters, requirements, testing, inspection rules, marking, packaging, transport and storage.
CECS 344:2013	Technical specification for construction of ground heat exchanger in ground-source heat pump system
JB/T 12841-2016	*Low ambient temperature air source heat pump water heater* Summary This standard specifies the terms and definitions, type and basic parameters, requirements, test methods, inspection rules, marking, packaging, transportation and storage of low ambient temperature air source heat pump hot water machine (hereinafter referred to as hot water machine). This standard applies to the use of motor-driven, the use of steam compression refrigeration cycle to air as a heat source to provide hot water for the purpose, and in low ambient temperature conditions to produce hot water heat pump hot water machine.
JB/T 12840-2016	*Air source heat pump high temperature hot air&hot water unit* Summary This standard specifies the terms and definitions, type and basic parameters, requirements, test methods, inspection rules, marking, packaging, transportation and storage of air source heat pump high temperature hot air and

	high temperature hot water unit (hereinafter referred to as unit). This standard applies to the motor drive, the use of steam compression refrigeration cycle to the air as a heat source, providing 55 °C ~ 80 °C high temperature hot air or 65 °C ~ 80 °C high temperature hot water unit, higher than 80 °C unit can refer to the use.
JGJ 158-2018	*Technical standard for thermal storage air-conditioning system (Energy storage air conditioning engineering technical standards)*
GB/T 18837-2015	*Multi-connected air-condition (heat pump) unit* Summary This standard specifies the terms and definitions, types, models, and basic parameters, requirements, tests, inspection rules, marking, packaging, transportation and storage of multi-connected air conditioning (heat pump) units (hereinafter referred to as "units"). This standard applies to multi-type air conditioning (heat pump) units using Class A1 refrigerants specified in GB/T 7778. Units using A2L refrigerants and double refrigeration cycle and multi-refrigeration cycle can refer to this standard.
GB/T 18836-2017	*Ducted air-conditioning (heat pump) units* Summary This standard specifies the terms and definitions, types and basic parameters, requirements, tests, inspection rules, marking, packaging, transportation and storage of air duct (air pump) units (hereinafter referred to as "air conditioners"). This standard applies to duct air supply (heat pump) unit.
GB/T 19409-2013	*Water-source(ground-source) heat pump* Summary This standard specifies the water (ground) source heat pump (hereinafter referred to as "units") of the terms and definitions, types and basic parameters, requirements, test methods, inspection rules, marking, packaging, transport and storage....

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