



**HPT-Annex 46**  
Domestic Hot Water Heat Pumps

## Annex 46

# Test Procedures and Quality Labels for Heat Pump Water Heaters

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Phetradico



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## Preface

This project was carried out within the International Energy Agency Technology Collaboration Program on Heat Pumping Technologies (HPT TCP).

## 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 Program. 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 Program of energy technology and R&D collaboration, currently within the framework of over 40 Implementing Agreements.

## Disclaimer

The HPT TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programs or TCPs. The TCPs are organized under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the HPT TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

## The Technology Collaboration Program on Heat Pumping Technologies (HPT TCP)

The Technology Collaboration Program on Heat Pumping Technologies (HPT TCP) forms the legal basis for a Program of research, development, demonstration and promotion of heat pumping technologies. Signatories of the TCP, called participating countries, are either governments or organizations designated by their respective governments to conduct. The Program is governed by an Executive Committee (ExCo), which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

## Annexes

The core of the TCP are the “Annexes”. Annexes are collaborative tasks conducted on a cost-sharing and/or task-sharing basis by experts from the participating countries. Annexes have specific topics and work plans and operate for a specified period, usually a number of years. The objectives range from information exchange to the development and implementation of heat pumping technologies. An Annex is in general coordinated by an expert from one country, acting as the Operating Agent (manager). This report presents the results of one Annex.

## Triennial Heat Pump Conference

The IEA Heat Pump Conference is one of the three major products of the Technology Collaboration Program on Heat Pumping Technologies. The Executive Committee supervises the overall organization and its quality and selects from a tender procedure the host country to organize the Conference and establishes an International Organization Committee (IOC) to support the host country and the ExCo.

## The Heat Pump Centre

The Heat Pump Centre (HPC) offers information services to support all those who can play a part in the implementation of heat pumping technologies. Activities of the HPC include the publication of the quarterly Heat Pumping Technologies Magazine and an additional newsletter three times per year, the HPT TCP [website](#), the organization of workshops, an inquiry service and a promotion Program. The HPC also publishes results from the Annexes under the TCP-HPT.

For further information about the Technology Collaboration Program 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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## **Quote**

There is no single 'best' test method, which could be adopted for global use – all have their advantages and disadvantages.

## Summary

This report gives an overview of a disturbing landscape with a great number of test methods for heat pump water heaters in use in different regions of the world, with major differences between them, like:

- Product configuration (with or without storage tank, air or ground heat source, etc.) and heating capacity of the heat pump
- Temperature conditions in the test room
- Tapping profiles and temperature setting of the heat pump
- Calculation procedures of efficiencies (i.e. considering heat losses in the storage tank)

As a result, manufacturers have to undertake a different set of tests to be able to sell their products on the worldwide market. This inhibits trade, adds to product cost and slows the development of the global heat pump water heater market. Especially the 2014 SEAD report [01] (add a footnote) on 'Potential for Harmonization of International Test Standards' for heat pump water heaters concludes that: 'In an ideal form of harmonisation, testing authorities in each economy would be able to take the results from any of the existing HPWH tests, and use a simulation model to predict what the results would be if the same model were physically tested to their own standard. However, this ideal is not likely to be attainable'.

There is considerable work to be done before internationally-comparable energy efficiency test methods, metrics and efficiency levels are at a stage where they can be used in future efficiency policy measures. The ISO Working Group 12 on Heat pump water heaters of ISO Technical Committee 86/SC 6 has proposed a harmonisation framework, including standardised physical tests and a staged development of simulation methods. It recently published the ISO Draft HPWH-19967-Part1-DIS registration [21]. It is important to have accurate procedures for standard assessment of the energy performance of DHW-preparation. The question is whether the current and the future Energy Performance Standards that are widely used to evaluate applications actually reflect the current applications.

Standards are used for various purposes at legislative level and for other purposes:

- Energy performance labelling, like European ECO label, TOP Runner in Japan, China Energy Label (CEL), Energy Star and Energy Guide labels in North America
- In practice, standards are also used for design purposes used in a number of (often commercial) calculation models.
- Governmental information models, like the SAP (add abbreviation as footnote) and RdSAP models in the UK with which the EPC for the building is calculated
- Also Heat Pump Associations develop models

Traditionally, energy efficiency standards and labels have set performance requirements for water heaters by type (e.g., storage electric water heater, gas instantaneous water heater, etc.), thus inhibiting the comparison across water heater technology classes. Yet many of the test procedures seem to focus mainly on air source DHWHPs, being the main stream, while there is a large number of alternative heat pump technologies supplying domestic/sanitary hot water based e.g. on ground heat. For these there are sometimes no standardized test procedures available or if available not acknowledged at international level.

## **Disclaimer**

The information and analysis contained within this summary document has been developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as a guidance.

The market is developing fast and at the moment of publication some information can already be overtaken by new developments. There are some websites listed at the reference pages of the report.

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## 1. Introduction

The energy supplied to the water divided by the electrical energy consumed is generally called the Coefficient of Performance (COP) or the Energy Factor (EF). A well-designed DHWHP has a COP in the order of 4, however, DHW HPs are relatively more complex systems than straightforward heat pumps for space heating as commonly a storage tank is included. Testing and predicting the overall performance is not straightforward as it can vary with the following:

- Climatic conditions, especially for air source systems using outside air as source, less for ground source systems;
- Cold water temperatures supplied to the DHW HP
- Hot water temperature setting, often as a consequence of legislation, in relation to the temperature of the source (i.e.  $\Delta T$ ).
- Heat transfer system, especially the condenser in relation to the storage tank;
- Heat losses of the storage tank;
- Quantity of hot water usage, draw-off profiles and stratification during draw offs.
- Control strategy and thermostat setting and temperature difference in storage tank

When testing a DHW HP, the same HP can give different outcomes according to different world wide test procedures (apart from variations in results between different laboratories). Some only measure the COP during the period when the unit first heats the water from cold, others take into account the COP during a series of hot water draw-off and reheating cycles, and some take into account the energy used to maintain the hot water at storage temperature during periods when no hot water is being drawn off. A further complication is that some procedures report a 'seasonal' value that is weighted according to how performance is expected to change over the year, as ambient conditions, hot water loads and inlet cold water temperatures vary. This weighted value is often called the 'Seasonal COP' (SCOP) value.

An overview and analyses of test procedures is given by SAED in their final [report](#) from 2013 [01]. The focus of that report has been solely on air to water models suitable for domestic hot water, where the vapour compression cycle is driven by an electric motor-powered compressor. This air to water DHW HP is the concept appearing as most applied in the market.

However to make it complex, there is a number of heat pump alternatives on the market for hot water heating like: direct gas driven heat pumps, absorption heat pumps, solar supported heat pumps, booster heat pumps and not forgetting the double function heat pumps (for space heating and hot water) and freshwater heat pump systems. Especially the double function heat pump is dominating more and more the Northern European market where ground sources are often used and the market for air source systems is growing.

Next to that is that since the SAED report especially in Northern America the general test procedures for domestic hot water appliance has been changed, effectuated by January 2018.

Test procedures for larger capacities (>80kW) are not available, while these heat pumps are often standardized for collective systems.

## 2. Test standards

There are a great number of test methods for heat pump water heaters in use in different regions of the world, with major differences between them. As a result, manufacturers have to undertake a different set of tests to be able to sell their products on the worldwide market. This inhibits trade, adds to product cost and slows the development of the global heat pump water heater market.

There is considerable work to be done before internationally-comparable energy efficiency test methods, metrics and efficiency levels are at a stage where they can be used in future efficiency policy measures. A harmonisation framework is proposed for this purpose, including standardised physical tests and a staged development of simulation methods.

### 2.1 Asia

The major economies like Japan, Korea and China have a number of standards for testing DHWHPs. These standards often take into account the cultural difference in water usage.

#### 2.1.1 Japan

Compared to the average Western European daily domestic hot water usage, the average Japanese usage is much higher because of the habit of taking hot baths (among others). This means that the function of a water heater is adapted to this and that test methods for water heaters take this into account. A bath function is a specific Japanese application where bath water can be drawn into the water heater to be reheated and then discharged again into the bath. This allows the bath temperature to be maintained for long periods. A similar bath reheat function is provided by a number of the heat pump water heaters.

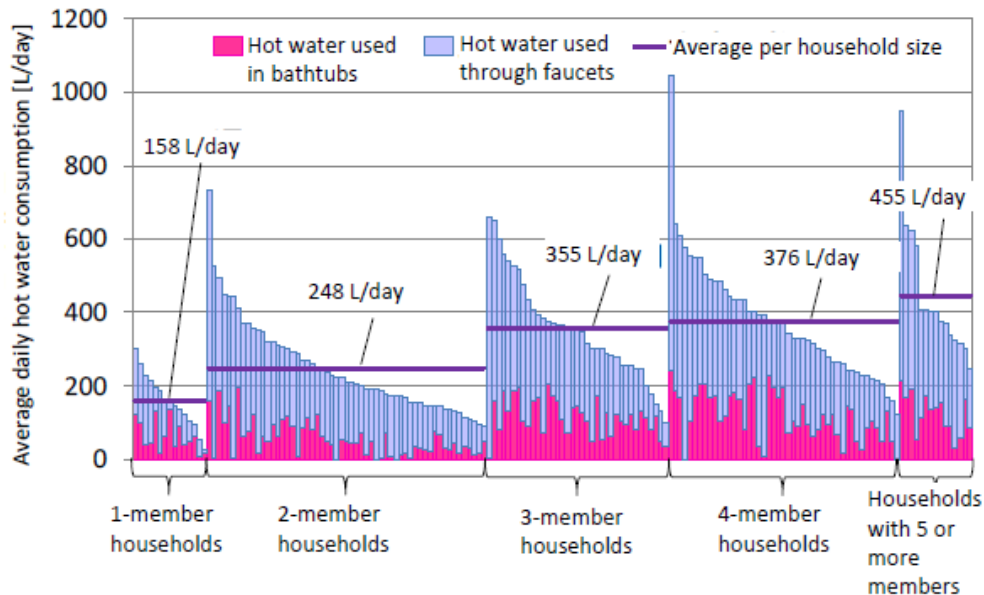


Fig 2.1 Hot water use per household in Japan [32]

The test method for Heat Pumps in Japan (JIS C 9220-2011) Residential Heat Pump Water Heaters is extensively described under the IEA TCP 4E ([Energy Efficient Energy Equipment](#)) in their benchmark studies.

This standard is to be used in the design and manufacture of water heaters for hot water supply facilities primarily in the home (bathroom and kitchen). This standard covers electric vapour-compression type heat pumps that use as a refrigerant hydrofluorocarbons (HFC) or carbon dioxide (CO<sub>2</sub>) (note that Top Runner and the data set

provided only covers CO2 refrigerant systems). The heat pump system consists of air heat exchangers, a hot water tank and hot water control devices such as those defined for use in the water heater.

This standard does not apply to the following types:

- where the capacity of the refrigerant circulation system is greater than 11.58 kW
- that uses an HFC refrigerant that is either toxic or flammable combined with a temperature greater than 35°C, making the saturated vapour pressure exceed 3MPa, or alternatively if the refrigerant circulation system is equal to or greater than 19.3kW.
- the connection refrigerant pipe, hot water storage unit and pump unit are separable; there is no water storage on the premises; or heat source other than electricity is present.

**Summary of the Japanese Test Procedure** The water heater is filled with cold water and allowed to operate until thermostat cutout. Hot water is drawn off and the tank is allowed to recover. This is repeated until the recovery energy is within a specified repeatability. The test then proceeds into a series of 24 hour drawoffs. The drawoffs are specified for:

- Standard house (455.74 litres at 40°C) and small house (277.96 litres at 40°C)
- Summer, intermediate and winter draw off profiles

The volume patterns are the same for each season – only the cold water supply temperature and the outdoor air temperature (for the evaporator and tank heat loss) varies by season.

**Test Conditions and Procedures** Two main types of heat pump water heater are specified in the test:

- System with an intermediate holding tank
- System without an intermediate holding tank
- The temperatures for the test are set out in Table 2.1:

For the measurement of the energy consumption efficiency of heat pump water heaters, the measuring method is based on actual usage, which is stipulated in JIS C 9220“Residential Heat Pump Water Heaters” of year 2018, shall be adopted.

Energy consumption efficiency of a heat pump water heater is the ratio of heat quantity transferred to circulating hot water to electric power consumption per time unit when the heat pump is operating. It is expressed as “annual water heating and heat-retention efficiency” in case of heat pump water heaters with a bath water heat-retention function and as “annual water heating efficiency” in case of those without said function, both of which shall be measured by the method stipulated by JIS C 9220 (see Attachment) and calculated by the following formulae.

Table 2.1: Ambient and water test conditions in JIS C 9220<sup>1</sup>

Season	Ambient air °C <sup>§</sup>	Cold water inlet °C
Intermediate (TC1)	DB 16°C, WB 12°C	17°C
Summer (TC2)	DB 25°C, WB 21°C	24°C
Winter (TC3)	DB 7°C, WB 6°C	9°C

Annex A of JIS C92220 specifies the setup for testing and Annex B sets out the measurements required to measure energy consumption.

<sup>1</sup>DB – Dry Bulb Temperature; WB – Wet Bulb Temperature

Initially the tank is allowed to heat up and repeatability of recovery energy is established (stable operation).

Following this initial testing, there are a series of complex 24 hour draw off patterns as follows:

- Hot water delivery temperatures are specified as 40°C -2K +0K (even though storage temperature is higher)
- There are 4 different draw off types: wash basin, kitchen, bath, shower.
- Flow rates for wash basin and kitchen is 5L/min. Flow rates for bath are 10-15L/min and shower is 10L/min.
- Wash basin and kitchen events are generally less than 5L, a few to 25L, shower 20L or 50L, bath 180L
- Standard household and Small household profiles are specified by 3 seasons
- Standard winter: 51 draws, 16.276 kWh (58.594 MJ), nominally 455.74 L at 40°C equivalent (cold water 9°C)
- Standard intermediate - 51 draws, 12.076 kWh (43.473 MJ), nominally 455.74 L at 40°C equivalent (cold water 17°C)
- Standard summer: 51 draws, 8.401 kWh (30.242 MJ), nominally 455.74 L at 40°C equivalent (cold water 24°C)
- Small winter: 31 draws, 9.927 kWh (35.737 MJ), nominally 277.96 L at 40°C equivalent (cold water 9°C)
- Small intermediate: 31 draws, 7.365 kWh (26.515 MJ), nominally 277.96 L at 40°C equivalent (cold water 17°C)
- Small summer: 31 draws, 5.124 kWh (18.445 MJ), nominally 277.96 L at 40°C equivalent (cold water 24°C)

Table 2.2: Assumed hot water demand conditions for three seasons in JIS C 9220

Schedule name	Number of Draws	Daily load kWh/day in hot water	Daily load MJ/day in hot water	Average MJ/draw
Std Winter	51 (56) *	16.276	58.594 (62.714)	1.149
Std Intermediate	51 (56) *	12.076	43.473 (46.533)	0.852
Std Summer	51 (56) *	8.401	30.242 (32.103)	0.593
Small Winter	31 (34) *	9.927	35.737 (37.471)	1.153
Small Intermediate	31 (34) *	7.365	26.515 (27.799)	0.855
Small Summer	31 (34) *	5.124	18.445 (19.221)	0.595

The volume and energy details of the 6 draw off patterns are shown in Table 2.2.

The energy input, energy output and COP for each draw off profile is then calculated.

Annex C then specifies how to calculate the seasonal annual energy consumption for the heat pump water heater. There are two climate profiles: a standard climate and a cold climate. The annual performance measure for each climate essentially specifies a number of days at each average daily ambient temperature. The standard climate specifies the number of days for each daily average temperature ranging from 0°C to 30°C in 1K increments. The cold climate specifies the number of days for each daily average temperatures ranging from -9°C to 26°C in 1K increments. The performance at each daily average temperature bin is determined by interpolation (or extrapolation) of the measured values for the three seasons tested.

## 2.1.2 Korea

Korea has an export driven economic structure. All products manufactured in Korea are basically exportable. It is also an international trend to directly adopt IEC or ISO as domestic standards. Korea has been one of the initiators of the SEAD report 'Potential for Harmonization of International Test Standards', where the Korea Testing Laboratory (KTL) was one of the main suppliers of data and driving forces behind the study [01].

### (Korea Industry Standard KS (KS B 6410))

The KS standard for household air heat source heat pump boiler (KSB 6410) was enacted and came into force on February 5, 2014.

Table 2.3 – Definition of KS B 6410 [33]

<b>Standard Number</b>	<b>KS B 6410</b>
<b>Standard name (Korean language)</b>	가정용 공기열원 열펌프 보일러
<b>Standard name (English)</b>	Air source heat pump boiler for residential buildings
<b>Classification</b>	<a href="#">B-machine</a> > <a href="#">heat using machinery-gas instruments</a>
<b>Application</b>	This standard is used for an equipment which heat pump boiler is operated with air heat source, generators hot water and stores in a heat storage tank, directly for heating only, hot water supply only, or heating/hot water supply without a heat storage tank. It is applied to household air heat source heat pump boiler (hereinafter referred to as "heat pump boiler") that has a rated heating capacity of 23,000 W or less and the maximum pressure of the heat storage tank is 0.34 MPa or less. All performance tests carried out with this standard are limited to heat pump boilers, not including thermal storage tanks.

Content: Scope of application, citation standard, material and structure, test condition, performance, test, inspection, product naming method, display and instruction manual

- Scope of KS standard
  - Heat source: air
  - Output: hot water
  - Application: Heating only, hot water supply only or heating/hot water supply
  - Rated capacity of heating: 23kW or less
  - Maximum working pressure when using thermal storage tank: 0.34MPa
  - Heating methods: Direct heating method, indirect heating method (heat exchange type, internal coil type, mixed type)
- materials
  - Heat storage material: Water (water storage type), latent heat material (latent heat storage type)
- structure
  - Separate type: Water outlet unit and heat storage tank are installed in the room
  - Integral type: Outdoor unit and entrance/exit water unit installed outdoor

- Rated voltage: Single phase AC 220 V, three phase AC 220 V, 380 V, 440 V, 220 · 380 V dual use or 380 · 440 V dual use, frequency is 60 Hz
- Heating performance: Automatic heat operation is carried out after setting heat pump boiler access water temperature under standard heating condition and cold district heating condition without auxiliary heating device being operated, and the measured capacity and power consumption
- Test condition for heating: Separated into the standard condition and the cold district condition, the power consumption is obtained from the total value of the power consumption of the indoor/outdoor unit of the heat pump boiler which the electricity meter reads. The heating capacity is 95% or more of the manufacturer's notation value under all conditions and the power consumption should not exceed 110% of the power consumption determined by the manufacturer under all conditions.
- The annual efficiency shall be 96% or more of the manufacturer's specified labelling value when tested by the annual efficiency testing method. It is a test for heat pump boiler to measure heating efficiency during heating period and will measure the overall efficiency of the heat pump boiler and measure by giving weight value of outside air temperature by area such as cold district, average.
- Standard/cold region hot water supply capacity and power consumption: Test is conducted in which the auxiliary electric heating device is not operated, and a value is obtained by arithmetically averaging the hot water supply capacity calculated for each of the entrance and exit water temperature conditions

Table 2.4 SCOP weighted values [33]

SCOP 加重值				
Temperature	COP	Cold district	Average	Warm district
-15℃/-	COP@15	7%	2%	0%
-7℃/-	COP@7	39%	22%	5%
2℃/1℃	COP@2	39%	48%	48%
7℃/6℃	COP@7	15%	26%	47%
KSCOP		SCOP_C	SCOP_M	SCOP_W
$SCOP_C = 0.07COP@15 + 0.39COP@-7 + 0.39COP@2 + 0.15COP@7$ $SCOP_M = 0.02COP@-15 + 0.22COP@-7 + 0.48COP@2 + 0.28COP@7$ $SCOP_W = 0.05COP@-7 + 0.48COP@2 + 0.47COP@7$				

## 2.2 North America

In North America, both Canada and United States have more or less harmonized their test procedures.

### 2.2.1 United States

The U.S. Department of Energy (DOE) initiated a rulemaking to consider amendments to its old test procedures for covered residential and commercial water heaters as per recommendation of The American Energy Manufacturing and Technical Corrections Act (AEMTCA). Based on extensive testing, a new performance evaluation procedure was defined. According to the new procedure the set point for water temperature is 125°F (51.7°C) and the test condition for inlet water and ambient air temperatures are prescribed as 58°F (14.4°C) and 67.5°F (19.7°C) (35 to 45% relative humidity) respectively.

The US procedures for both pre-2013 Energy Factor (EF) and post-2013 Uniform Energy Factor (UEF) are designed to account for tank heat loss effects over a 24-h test period and to normalize test results to standard ambient air and tank water temperature conditions.

**The First Hour Rating (FHR)** is a measure of the available hot water capacity of the WH (in gallons). According to the new DOE test method, hot water (125±15°F) is drawn from the tank as long as the leaving water temperature is 67±2°F higher than the entering water temperature. Once the leaving temperature drops below the prescribed limit, the supply is stopped until the set point of 125±15°F is met again, followed by another draw. Following this

procedure, the total water drawn from the tank during one hour indicates the total capacity of the heat pump and electric resistance heaters.

**The Unified Energy Factor (UEF)** is a measure of the efficiency of the system per the most recent standard test methods and procedures (DOE 2013). It accounts the ratio of the net amount of heat gained by the system (by heating the water) at the end of the test period to the total power required to operate the system. The previous EF test procedure used a single water draw pattern – six equal water draws of about 10.7 gallons each spaced equally during the first five hours of the EF test – applied to all WHs (including HPWHs) with a storage tank. In contrast, the new method uses the measured FHR value to define the draw pattern used for the UEF test. Tables 1 to 3.4 in Addendum 1 provide details of the draw patterns for storage water heaters based on FHR. Four different usage patterns are defined ranging from very small to high. One of these four specified water draw patterns is used to determine the UEF.

The Coefficient of performance (COP) measures the performance of the heat pump. It is important to differentiate between UEF and COP. The heat pump's COP is always higher than the UEF because, because the energy lost through the tank wall and insulation (also known as skin effect) is also included in the heat supplied by the heat pump and hence results in a larger number. UEF is the performance of the system based on how much energy is used to heat up the water delivered from the tank, the ultimate goal of the system, while COP represents the performance of heat pump only.

The current test procedure to comply with the standards can be found at the governmental [website](#) of the Electronic Code of Federal Regulations under PART 430—Energy Conservation Program for Consumer Products, Subpart B—Test Procedures.

- US Code of Federal Regulations Title 10, Part 430, Appendix E to Subpart B (CFR 430)
- AHRI Standard 1300 (I-P) *Standard for performance rating of commercial heat pump water heaters*, Air-conditioning, Heating and Refrigeration Institute
- ASHRAE 206-2013 *Method of Testing and Rating of Multipurpose Heat Pumps for Residential SpaceConditioning and Water Heating* (ANSI Approved)

In the standards mentioned, the future primary energy conversion efficiency will be calculated with primary energy factors that are based on the present. Future expansion of renewable energy over the next ten years will lead to significant reductions of this factor, but the standards reflect only the present status. Furthermore, the central component of a hot water system has a useful life of several decades. In comparison with conventional systems an IWH system will become increasingly more primary energy efficient during its useful life.

In 2015, the Department of Energy (DOE) issued a new **test procedure** [22] for residential and some commercial water heaters. The new procedure addresses a number of longstanding testing issues in order to better replicate real-world usage and to more accurately measure energy consumption across various technologies. Unfortunately, the DOE missed an opportunity to ensure that one of the most energy-efficient technologies, the electric heat pump water heater (HPWH), performs as expected in cold temperatures. Regional efforts are underway to address variations in cold temperature performance, but DOE should address this issue soon so that HPWH performance can be accurately measured across the board.

The new test procedure is designed to more accurately measure the energy consumption of technologies that are becoming increasingly popular, such as tankless-, heat pump- and gas condensing water heaters. To better simulate consumer use, manufacturers will now be required to test their units using water usage patterns based on water-heater capacity and to heat the water to 125°F (the temperature setting at which units are commonly shipped). These new requirements have been largely derived from extensive field studies.

The HPWH offers one of the largest energy saving opportunities available. A [2012 ACEEE/ASAP study](#) estimates that savings from potential HPWH standards could reach more than 400 billion kWh in cumulative electricity savings through 2035, enough to power over 37 million homes in the U.S. for one year. Individually, EPA

estimates[23] that units save US \$250 a year in electricity bills when compared to standard electric-storage water heaters and that the higher purchase price can be recouped in about 3 years.

Household Size	Annual Savings	Annual Savings	Payback	Lifetime Savings
no	kwh	\$	Years	\$
2	1,35	160	4.9	1,34
3	2,02	240	3.3	2,4
4	2,69	330	2.5	3,47

Table 2.5 Savings and Paybacks for ENERGY STAR Heat Pump Water Heaters [23]

**2.2.2 Canada**

CAN/CSA-C745-03 (R2014) is the National Standard of Canada for Energy Efficiency of Electric Storage Tank Water Heaters and Heat Pump Water Heaters. It was published by the Canadian Standard Association (CSA) in 2003 and reaffirmed in 2014. Here is the scope of the standard:

- The Standard specifies the methods for determining the energy factor for electric storage tank water heaters and heat pump water heaters.
- The Standard establishes minimum energy efficiency levels for electric storage tank water heaters and heat pump water heaters.
- The Standard applies to:
  - electric storage tank water heaters:
    - with volumes of 76 to 454 L (20 to 120 US gal);
    - having electric heater elements with power inputs up to 12 kW; and
    - designed to heat and store water at a thermostatically controlled temperature equal to or less than 82°C (180°F)
  - heat pump water heaters that have:
    - a maximum current rating of 24 A;
    - a single-phase maximum voltage of 250 V; and
    - Ancillary equipment necessary for the device to function.
- The Standard does not apply to high-temperature water heaters.
- The tests contained in the Standard are not intended to represent actual efficiencies realized in the field. Instead, these tests provide a standardized method of comparing performance.
- The Standard is written in SI units. The values given in parentheses are for information only. The SI values have been calculated from the US Customary Units measurements found in the US Department of Energy publication 10 CFR, Part 430, appendix E, subpart B.

## 2.3 Europe

The European standard EN 16147 specifies the tests for determining the COP and other aspects of performance, but does not specify minimum values for these (in Europe, minimum performance requirements are defined at EU level by Ecodesign Directive, and at nation level through building codes). It does specify that if the manufacturer decides to provide information about the performance of a model it must be with reference to one of the standard draw-off schedules.

### 2.3.1 Netherlands

Current DHW heat pump technology/practice and compliance with the Dutch Standards and Test Procedures is subject to research, commissioned by the Dutch Enterprise Agency and executed by the independent consultancy Entry Technology. In the project, several incompatibilities between the heat pump practice and the governing standards are identified.

On the basis of the research it is recommended to:

- Harmonise the Dutch Standard (NEN7120 and future NTA8800) with the European standards EN16147 and EN13203.
- Standardise and test DHW heat pumps:
  - at variable source temperatures (reflecting the variability of ambient conditions and smart control of heat pumps).
  - at variable power rates, just like is done with heat pumps for space heating (EN14825).
  - at variable supply temperatures (reflecting the variability DHW-usage).

In addition, regarding the design of DHW-heat pumps it is recommended to focus also on optimisation of (variable) power rate and store volume. These aspects are relevant in relation to the reduction of demand of individual and also collective systems (depending of the synchronicity of the load).

Given the market development, it is recognised that DHW-heat pumps are an important instrument in the renewable energy transition. A better fit to changing conditions and demands will further enhance the CO<sub>2</sub>-reduction potential of DHW-heat pumps”

Additional standards have been develop for:

- Solar thermal supported heat pumps
- Booster heat pumps for DHW

### 2.3.2 Switzerland

For DHWHPs the heat pump test center WPZ (“WärmepumpenPrüfzentrum”) at NTB University of Applied Sciences of Technology Buchs follows the testing standard EN 16147. The DHWHPs are measured at 2°C (colder), 7°C (average), 14°C (warmer), 20°C (indoor air) (see Table 4 of EN 16147).

The performance tests consist of the following principal stages (see Figure 2.1 of EN 16147):

- A. Filling and heating up time
- B. Standby period (min. 48 h), to determine standby power input
- C. COP measurements at defined water draw-offs (min. 24 h) (e.g. hand washing, bathing, dish washing, etc.)
- D. Mixed water at 40°C, determination of the reference hot water temperature and quantity of usable hot water

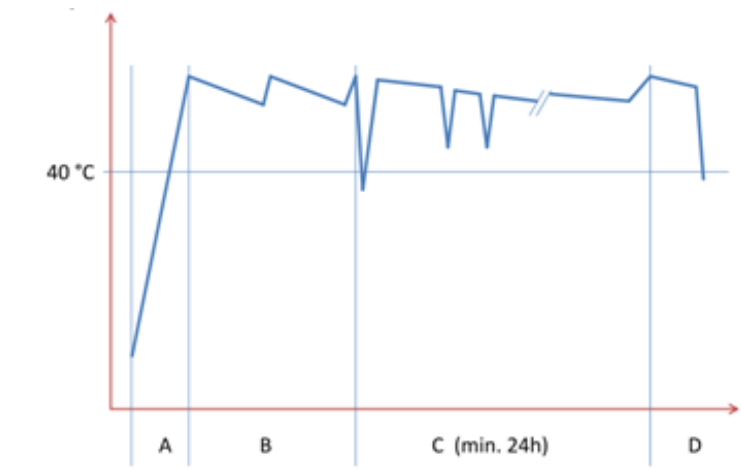


Fig 2.2 Stages of the Swiss performance test for DHW HP

The minimal COP requirements for DHWHPs (heat pump boilers) at different tap profiles are defined in the “Gütesiegel-Reglement” (add to References or as footnote). The required COP values according to EN 16147 depend on the storage tank volume, the tap profile and the air source condition. The actual storage tank volume may deviate from the nominal content by max. 5 %.

Table 2.6: Minimum required COP and test conditions to receive the quality label “Gütesiegel” in Switzerland.

Storage tank volume (L)	Load profiles according to EN 16147	Minimum required COP at air source conditions	
		A20	A7
< 150	M	3.2	2.3
150 to 249	L	3.2	2.3
250 to 349	XL	3.2	2.3
350 and higher	XXL	3.2	2.3



### 2.3.3 Germany

The Association of German Engineers (VDI) standards VDI 2067 Blatt 12 is of fundamental importance for the primary energy efficiency of the hot water supply. This standard specifies certain ranges of values and mean values for the “reference usage” of water and the demands for hot water. However, it does not sufficiently differentiate between types of usage and the corresponding amounts of water. Accordingly, and as the case more often is, a quick shower suffices to clean the body. Whereas with the more infrequent “feel good shower” a lot more hot water is consumed. The sampling mentioned earlier certainly indicated that the demands and consumption are considerably over-estimated.

The statutory specifications relevant to hot water supplies that applied during the period of investigation were above all the Energy-Saving Ordinance (EnEV) and the associated DIN 4701-10 and DIN 18-599 standards. Based on the findings of this study the following elements of these standards are problematic: The effective energy for hot water is prescribed according to floor space as between 12 and 16 kWh per square meter. These standards suggest that on the one hand the hot water needs of a building increase in direct proportion to the floor space, and on the other hand that the ratio of these values is constant nationwide. These assumptions do not correspond to real conditions and hence are inaccurate. Thus, they lead to modelling and planning of buildings that is divorced from reality. The errors that arise from this become even more discrepant with falling hot water consumption and so must be corrected.

The consumption of the effective energy in hot water should be determined and defined as it relates to persons. Realistic life cycle variations and further measures should also be determined and defined, which will promote increasing energy efficiency in the supply of hot water. This is a particularly decisive factor for fostering innovation.

Start-up wastage due to slugs of water in long pipes has yet to be explicitly recorded in the relevant DIN standards and so do not figure in calculations of kilowatt-hours per month. Assessment of this factor would be preferred.

## 2.4 Conclusions

As described in the former section, there are a great number of test methods for heat pump water heaters in use in different regions of the world, with major differences between them. In an ideal form of harmonisation, testing authorities in each economy would be able to take the results from any of the existing HPWH tests, and use a simulation model to predict what the results would be if the same model were physically tested to their own standard. However, this ideal is not likely to be attainable.

The similarities between the currently in used tests methods are:

- All of them are carried out in controlled ambient conditions of temperature and humidity.
- All involve heating the water from 'cold' to 'hot', and measuring both the electrical energy consumed by the HPWH and the thermal energy added to the water.

However, the testing methods differ significantly with regard to:

- The categorisation of products by types, capacities and characteristics for the purpose of selecting the range of tests to be performed;
- The precise ambient conditions to be maintained in the test room and the variability limits permitted;
- The temperature of the inlet water and the variability limits permitted;
- The draw-off patterns;
- The methods of measuring and recording the temperature and heat content of the water in the storage tank (or in some cases, the outlet water only); and
- Whether the test covers performance during heat up only, or during physical tapping and standing heat loss as well.
- the water from cold, and those which involve actual draw-offs of hot water and subsequent reheating.

Of the tests currently in use, the Canadian, European, Japanese and USA test standards all involve hot water draw-offs. The final version of the Korean (KS) test being developed may include draw offs, although the early version did not.

There is no single 'best' test method, which could be adopted for global use – all have their advantages and disadvantages according to the SEAD report [01].

Given the extent of the differences, it is not considered likely that the standards bodies and energy program regulators in different countries would agree adopting a common standard, without a gradual process of confidence-building and harmonisation.

What are the next steps towards harmonization?

A set of guidelines can be developed for harmonisation;

1. Scope of testing procedure
2. Major objectives of the testing procedures (what parameters are to be established)
3. Identification of similarities among different procedures.
4. Level of complexity/duration of the test procedure
5. Scalability of the procedure to smaller vs. larger storage tanks
6. Applicability of various technologies (electric, gas fired, heat pump, tankless etc.)

Tables 2.7 and 2.8 below show the similarities and differences according to the SEAD report 2014 [01]. Included is also the draft ISO standard.

Configuration	USA, CFR 430	China GB/T23137/21362	Japan JISC9220-2011	Europe EN16147	Korea Draft (KS B ****)	ISO - Draft HPWH-19967- Part1
HP and tank in same casing (a) – location of installation not specified	Heat pump water heater with storage tank – integral	Packaged type	Single package	ND	Single package	ND
HP and tank in same casing – indoor tank location	ND	ND	ND	Factory-made units which can be ducted on airside	ND	Factory-made units which can be ducted on airside
HP and tank separate but supplied together – linked by water lines	Heat pump water heater with storage tank – separated	Split type		ND	Split type	ND
HP and tank separate but supplied together, linked by refrigerant lines	Heat pump water heater with storage tank – separated	Split type	Split	Split Heat Pump – outdoor heat exchange	Split	Split Heat Pump – outdoor heat exchange
HP sold separately – may be linked to any storage tank by water lines	HPWH without storage tank (also called ‘Add-on’)	Not directly defined, but test accommodates	Split	ND	Split	ND
Recirculating stand-alone heat pump	ND	Circulated heating HPWH	ND	ND		ND
Once-through stand-alone heat pump	ND	One-time heating HPWH	ND	ND		ND
Static heating HPWH	ND, but probably all of types 1-5	Water flows past heat exchanger by natural convection	ND	ND		ND
Off-peak product	ND	ND	Meets load without external energy supply 0700 to 2200	Meets load without external energy supply 0700 to 2200	ND	Meets load without external energy supply 0700 to 2200
Ability to heat water for hydronic space heating	No	No	ND	Possible but only domestic hot water production tested	Possible but only domestic hot water production tested	ND
Special configurations or designations	ND	ND	With ‘Intermediate holding tank’ for bath recirculation	With ‘smart control’ to adapt to individual usage conditions	ND	ND

Table 2.7 - Terminology for product configurations (ND = Not specifically defined in this standard, but not necessarily excluded. (a) Refrigerant condenser may be in or on the tank, or there may be separated by water circulation lines but within the same casing.)[01]

Configuration	USA, CFR 430 Canada CSA-C745-03	Europe EN16147	Japan JISC9220-2011	Korea Draft (KS B ****)	ISO - Draft HPWH-19967-Part1
Scope	Electric storage 76L to 454L, Heat pump to 24A single phase 250V	Heat Pump – air water or brine source, domestic HW only	Household air source heat pump (HFC or CO2) with tank	Air source heat pumps for hot water and space heating, with or W/O tank	Air source heat pumps for hot water and space heating, with or W/O tank
Test Chamber	Wooden platform and walls	Avoid direct radiation	Insulated chamber (calorimeter)	Insulated chamber (calorimeter)	
Ambient Air Test Conditions (TC)	19.7°C ±0.5°C (67.5°F) 49% to 51% RH	Evaporator 7°C WB 6°C (RH 86.8%) Tank (indoor) 20°C	TC1 (mid season) DB 16°C ± 1K WB 12°C ± 0.5K TC2 (summer) DB 25°C ± 1K WB 21°C ± 0.5K TC3 (winter) DB 7°C ± 1K WB 6°C ± 0.5K	Standard DB 7°C WB 6°C Severe Cold Zone DB -15°C WB NS	Outside air: Evaporator 7°C WB 6°C Tank (indoor) 20°C Air from non heated space: Evaporator 15°C WB 12°C Tank (indoor) 15°C Exhaust air: Evaporator 20°C WB 12°C Tank (indoor) 20°C
Air flow	Not stated	< 1.5 m/s	Not stated	ISO5151 Annex A/C/D	
Cold Water Supply	14.4°C±1°C (58°F)	10°C ±0.20K	TC1 17°C ± 2K TC2 24°C ± 2K TC3 9°C ± 2K	Low 15°C±0.15 K Midum 30°C±0.15 K High 40°C±0.15 K	10°C ±0.20K
Thermostat setting for test	57.3°C ±3K (135°F ±5°F)	Nominally 55°C (temperature rise 45K)	Normal ≤65°C (Winter hot >65°C) (Sanitary = max)	Manufacturer's instructions (nominal 50°C)	
Water Pressure	275kPa to rated	Not specified		≤ 343 kPa	Not specified
Installation	Installed in accordance with manufacturer's instructions	Installed in accordance with manufacturer's instructions (excluding optional accessories).	Installed in accordance with manufacturer's instructions.	Installed in accordance with manufacturer's instructions	Installed in accordance with manufacturer's instructions (excluding optional accessories).
Tanks Sensors	6 equal volumes	Not specified #	Inlet and outlet only #	Inlet and outlet only	Inlet and outlet only
Daily Drawoff Volume	243.4L	5 from S=36L to XXL=420L ***	Standard 455.7 L (40°C) Small 278.0 L (40°C)	none	5 from S=36L to XXL=420L ***
Drawoff energy	43.7 MJ	7.5MJ to 87.9MJ	See separate table	Not applicable	
Drawoff Flow rate	11.4 L/min	4 or 10 L/min	5 or 10 L/min	Not applicable	4 or 10 L/min
Heat Loss	Standby part of test	Not directly measured, but included in standby power input	To be confirmed	Not directly measured	
Performance tests included	First hour rating (volume for temperature drop of 13.9K) Volume	Heat up test Standby power (heat loss) Max temp and hot water delivery (40°C) Operating range Safety Safety	Safety Various performance Design and construction	Safety Material Structure Performance for Space heating Performance for sanitary water supply Seasonal COP Noise	
Test Point Period	Water draw off with normal water heater operation until the heat source cuts in, stop the draw and wait until the maximum mean tank temperature is achieved				

Table 2.8 - Summary of Test Conditions for Heat Pump Water Heater Test Methods [01]

Some of these heat pump test methods appear to draw on air conditioner test methods such as ISO5151. Some specify a calorimeter for testing. The air temperatures are similar to some air conditioner temperatures (e.g.USA ambient conditions are similar to ISO5151 indoor heating (and outdoor minimum cooling), EN (Europe) and JIS are the same as ISO5151 H1 outdoor heating conditions, Korea Low temperature and Cold Zone ambient temperatures for space heating tests are the same as ISO5151 outdoor heating conditions (H2 and H3 respectively).

Korean standard has additional outdoor conditions for testing for space heating to evaluate SCOP (seasonal coefficient of performance):

- Standard DB 7°C and WB 6°C, hot water inlet 40°C (loop), outlet 45°C (same as hot water production except 15°C inlet, 50°C outlet).
- Low temperature DB 2°C and WB 1°C, hot water inlet 40°C (loop), outlet 45°C.
- Cold Zone DB -7°C and WB -8°C, hot water inlet 40°C (loop), outlet 45°C.
- Severe Cold Zone DB -15°C and WB N/S, hot water inlet 40°C (loop), outlet 45°C (same as hot water production except 50°C outlet (inlet temperature under consideration)).

The US test standards define First Hour Ratings as a measure of the available hot water capacity of the WH (in gallons).

The draft ISO standard is included as far as the parts are defined [21].

Standard	Number of schedules, names	Number of Draws	Daily load KWh/day in hot water	Daily load MJ/day in hot water	Average MJ/draw	Annual load GJ/yr in hot water	Supply temp limits (below which draw discarded)
Canada CSA C745-03:2003	1	6	12.1	43.7	7.28	15.95	
China GB/T 23137-2008	N/A	N/A	N/A	N/A	N/A		N/A
China GB/T 21362-2008	N/A	N/A	N/A	N/A	N/A		N/A
Europe EN 16147:2011	S	11	2.10	7.56	0.69	2.76	N/A
	M	23	5.85	21.15	0.92	7.72	N/A
	L	24	11.66	41.95	1.75	15.31	N/A
	XL	30	19.07	68.65	2.29	25.06	N/A
	XXL	30	24.53	87.55	2.92	31.96	N/A
Japan JIS C 9220:2011	Std Winter	51 (56) *	16.276	58.594 (62.714)	1.149	Complex seasonal calculation interpolating measured values and specified days at 1K temperature increments	40°C
	Std Intermediate	51 (56) *	12.076	43.473 (46.533)	0.852		
	Std Summer	51 (56) *	8.401	30.242 (32.103)	0.593		
	Small Winter	31 (34) *	9.927	35.737 (37.471)	1.153		
	Small Intermediate	31 (34) *	7.365	26.515 (27.799)	0.855		
	Small Summer	31 (34) *	5.124	18.445 (19.221)	0.595		
USA CFR-430	1	6	12.1	43.7	7.28	15.95	Draw terminates when temp falls by 13.9°C from nominal storage temp of 57.2°C (ie to 43.3°C)
South Korea	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ISO - Draft HPWH-19967-Part1							

\* JIS C9220-2011 specifies some additional events associated with a heat exchange facility to reheat bath water. These events and the energy associated with them have been included in the total values shown in brackets. (a) A revision of the test standard is under way. It is planned to include draw-off tests for the purpose of determining minimum energy performance (MEPS) levels.

Table 2.9 Draw-off schedules [01]

### 3. Parameters for Test Standards

Testing and predicting the overall performance is not straightforward as it can vary with a number of outside factors such as climatic conditions, cold water temperatures, hot water temperatures as a consequence of Legionella legislation, control strategy, quantity of hot water usage, draw-off profiles and in house distribution losses. Clarification of a number of these effects is given underneath. Not yet all these factors are well researched as DHWHP's have not been a priority area for policy and researchers for a long time. A better understanding of these factors is desired in order to have adequate test procedures. These procedures are needed to improve the DHW systems, both in the initial design phase and in the final control phase.

#### 3.1 Definition of performance

COP is the ratio of the energy produced by the water heater to the energy used to operate the heat pump. In the lab, the researchers have temperature sensors in the tank so they can calculate the energy in the water. The EF is specified by the US DOE as a 24-hour lab test with a certain hot water draw pattern and monitoring period to observe tank heat losses. One step further is the efficiency labelled as Field Energy Factor (FEF) because it consists of observations at a range of outdoor air temperatures (OATs) and draw schedules. Further, it includes tank and plumbing losses as they occurred in field conditions. The "Field Energy Factor builds on the DOE term "Energy Factor" as a performance indicator in actual use. The FEF more closely approximates home use than a COP because it incorporates loss from cooling pipes between draws, cold water supply in winter, and other factors that impact energy use in the field. It can be compared to the European definition of SPF4 here below.

Basically the Energy Performance of the domestic hot water generator, the COP of the heat pump for DHW HPs, is the starting point of any calculation and thus of every decision. Under the European SEPemo project<sup>2</sup> the definition of COP for heat pumps in buildings has been broadened to four levels of performance definition, being:

- SPF1 - contains only the heat pump unit. It evaluates the performance of the refrigeration cycle and allows a calculation of the SPF of the heat pump without the auxiliary drives to show the efficiency of the refrigerant cycle
- SPF2 - contains the heat pump unit and the equipment needed to make use of the source energy available for the heat pump. This level of system boundary responds to the European [RES-Directive](#)<sup>3</sup> requirements for calculating the renewable energy used by the heat pump. SPF2 allows the calculation of the SPF including auxiliary drives for the heat source, but without back-up heater
- SPF3 - contains the heat pump unit, the equipment to make the source energy available and the backup heater. It represents the heat pump system and thereby can be used to compare heat pump systems with conventional heating systems e.g. oil or gas fired systems.
- SPF4 - allows a calculation of the SPF with the total produced thermal energy divided by the total energy consumption. This system boundary contains the heat pump unit, the equipment to make the source energy available, the backup heater and all auxiliary drives including the auxiliary of the heat sink system. SPF4 represents the heat pump heating system including all auxiliary drives which are installed in the heating system.
- This definition of SPF has been taken over by the European Commission in the [European Commission Decision 2013/114/EU from March 2013](#)<sup>4</sup> (establishing the guidelines for Member States on calculating

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<sup>2</sup> SEPemo project: <http://sepemo.ehpa.org/>

<sup>3</sup> Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

<sup>4</sup> In cases where several climate conditions are existing within the same Member State, the Member States should estimate the installed capacity of heat pumps in the respective climate condition area

renewable energy from heat pumps from different heat pump technologies pursuant to Article 5 of Directive 2009/28/EC of the European Parliament and of the Council) [08].

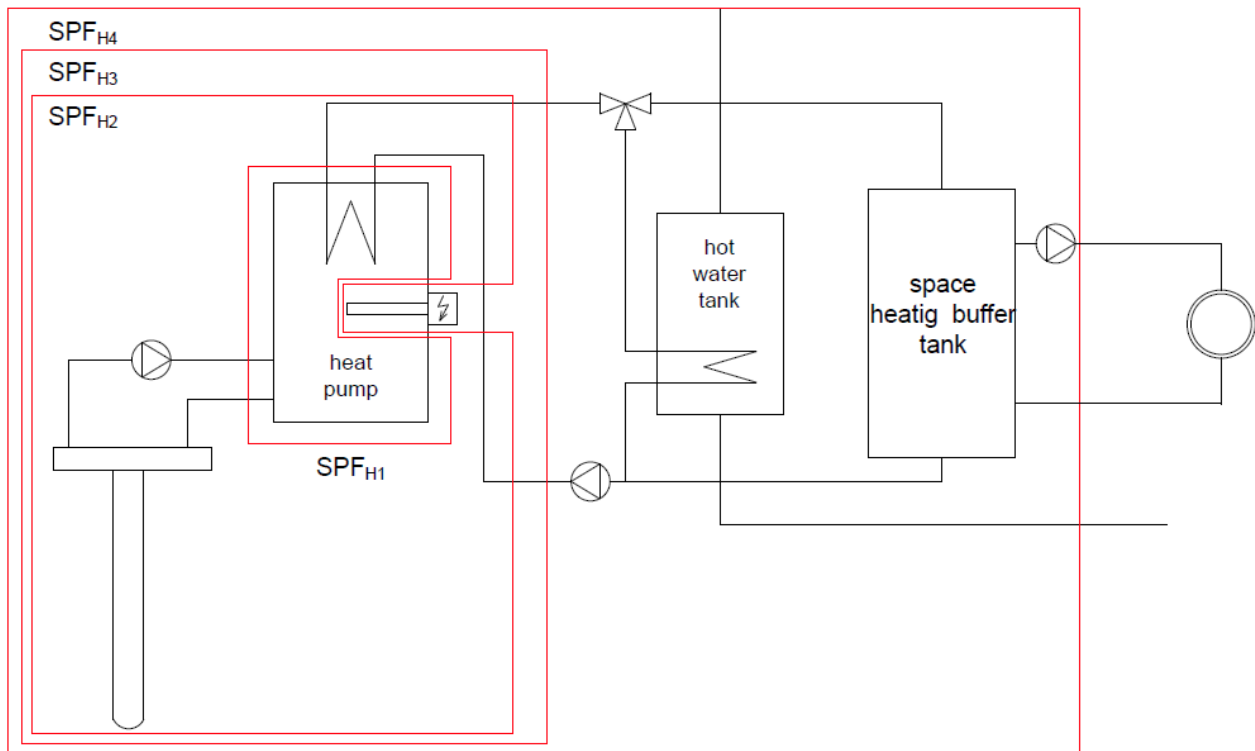


Fig 3.1 – SEPEMO definition of Seasonal Performance factors of a typical DHWHP with hot water tank and space heating buffer tank [24]

This SEPEMO definition describes the overall performance of a heating system taking into account a number of energy losses in the system. In fact, it does not describe the definition of a DHWHP and the various systems of hot water heating with heat pumps, like solar assisted heat pumps, booster heat pumps and fresh water systems, nor gas driven systems.

Focusing on stand-alone DHWHP the SPF definition SPF2, 3 and 4 become different.

- SPF1 - contains only the heat pump unit. It evaluates the performance of the refrigeration cycle and allows a calculation of the SPF of the heat pump without the auxiliary drives to show the efficiency of the refrigerant cycle.
- SPF2 contains the heat pump unit, **the storage tank** and the equipment needed to make use of the source energy available for the heat pump. Including the **storage tank** means that the specific technology and following aspects are taken into account
  - Cold water temperatures supplied to storage tank of the DHW HP and the hot water temperature setting, often as a consequence of legionella legislation, defining the energy needed to heat the tank and the condenser temperatures for the heat pump, i.e.  $\Delta T$  and thus the bare COP.
  - Heat transfer system, especially the condenser in relation to the storage tank, wrap around, internal spiral or auxiliary plate heat exchanger.
  - Heat losses of the storage tank;
  - Control strategy of the stored hot water and the characteristics of the thermostat ( $\Delta T$  in the on/off control).

In this part the source can be:

- Outside air source, which is very dependent on the climatic conditions
- Inside air source, which ventilation air and has an effect on the overall energy usage for space heating
- Low temperature heat distribution from a waste heat source or from another generator like a collective heat pump for space heating (this is for a booster type of heat pump – see Addendum 2)
- Solar thermal, which is fluctuating source dependent on incoming sunshine (this is for a solar supported heat pump – see addendum 2)

In all cases auxiliary drives for the heat source are needed which is included in the SPF2.

- SPF3 contains the heat pump unit, the equipment to make the source energy available and **the storage tank including any auxiliary heating, such as an electric resistance heater or an additional thermal solar heat exchanger**. This represents the overall DHWHP and can as such be used to compare with other domestic hot water generators, such as electric storage water heaters, gas fired storage water heaters, solar water heaters etc.
- SPF4 allows a calculation of the SPF of the overall system including in house distribution losses and taking into account the effects on the overall space heating system. This SPF4 is discussed in the Task 2 report as it contributes to the calculation of the overall energy performance of the building.

Some of the figures to calculate the SPF at the various levels are reproducible in tests different laboratories, but very dependent on the test methods discussed above which specify sensor location and higher instrumentation accuracy are likely to give more reproducible results. However, the tests may be more costly. The heat-up stage of testing could be specified in a way that makes it highly reproducible, if the ambient conditions, inlet water temperatures and in-tank temperatures are tightly controlled and monitored. The performance of heat pump water heaters is particularly sensitive to ambient conditions, so test standards, which cover more conditions, are likely to replicate actual use better – but the tests are more expensive to carry out.

Overall, this type of testing still only copies a static condition of the domestic hot water systems, whereas the dynamic performance and the use in practice ultimately determines the end result. The latter can only be simulated with tapping patterns that approach the practice.

### 3.2 Climatic conditions

For DHWHPs the heat source is a very important parameter as the temperature for the evaporator is a measure for the final COP. A number of sources are characterized by their temperatures in the standards, as shown in Table 3.1.

Table 3.1: Source temperatures ([EU-regulation No 812/2013](#)<sup>5</sup>)

Heat source	Outdoor air	Indoor air	Exhaust air	Brine	Water	LT Distribution
Temperature	+ 7 °C (+ 6 °C)	+ 20 °C (maximum + 15 °C)	+ 20 °C (+ 12 °C)	0 °C (inlet)/ – 3 °C (outlet)	+ 10 °C (inlet)/ + 7 °C (outlet)	+20 – 40°C (inlet) +10 – 30°C (outlet)

Especially for air source DHWHP the climatic conditions have a significant effect on the performance. Moreover, in US as well as European standards these are fixed at levels that may not reflect the application in practice where the outside temperature is fluctuating and can be ‘very low’. The temperature and humidity at the evaporator is one of the main determinants of the performance of an air-source DHW HP.

A single test condition may not be sufficient to indicate the performance of air source heat pumps sold across a wide geographical area and therefore operating in very different conditions.

<sup>5</sup><https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0812&from=EN>

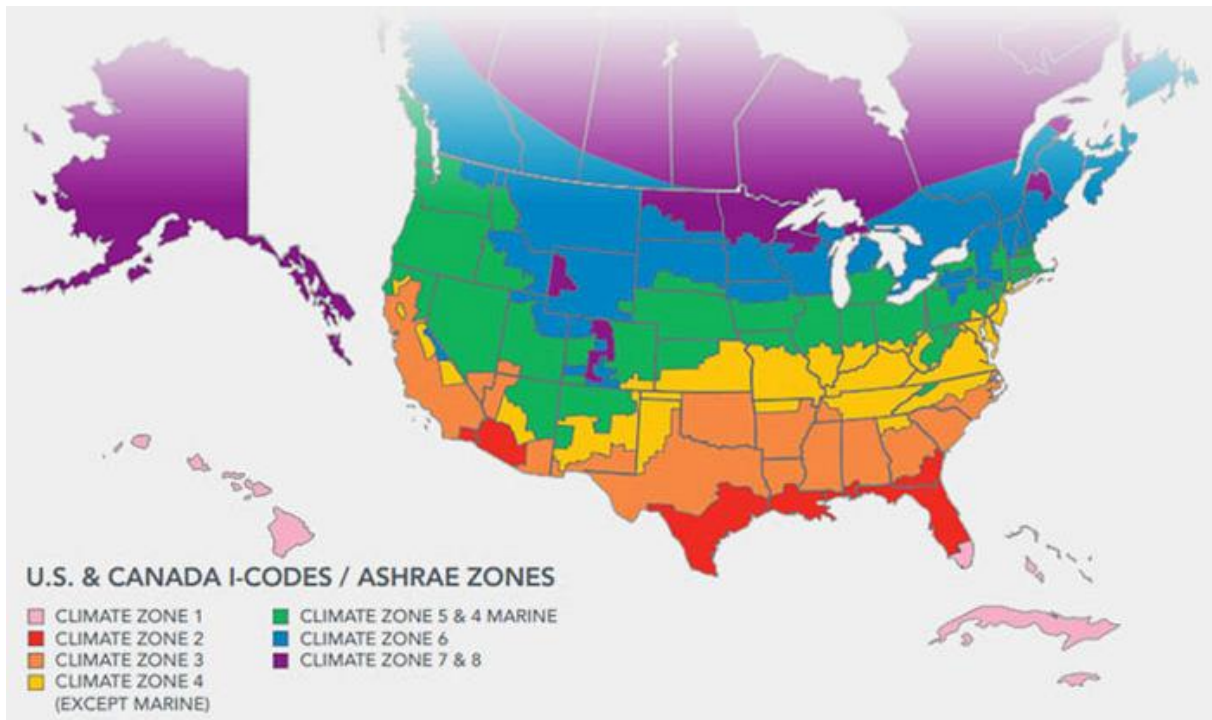


Fig 3.2 – Climatic regions in North America are determining factor for the Seasonal Performance

### US test procedures

The new US test procedure [22] does not test HPWH performance at low ambient temperatures as occurring in US climate zones 6, 7 & 8. HPWHs work by extracting heat from the surrounding air and transferring that heat to the water. However, during hours when the ambient temperature is too cold, the heat pump's compressor will shut down. When it shuts down, the water is heated by built-in resistance elements, which use about 3 times as much energy. Because of this sensitivity to low ambient temperature, performance can vary depending on where in the house the unit is installed and what region of the country the house is located in. This means that a unit installed in an unconditioned basement in northern Minnesota is likely to perform very differently from one installed in a garage in Florida.

Some HPWHs perform very efficiently in low ambient temperatures, but not all of them do. Heat pump compressors on some models shut down at temperatures as high as 57°F (13.9°C), while others continue to work down to 30°F (-1.1°C). But instead of acknowledging and accounting for these performance variations, the new DOE test procedure requires only that water heaters be tested at an ambient temperature between 66.5 to 68.5°F (19.2 to 20.3°C), making no distinction between the best and worst cold temperature performers. The DOE is advised to address this problem by requiring manufacturers to test HPWHs in lower ambient temperatures and, if possible, by setting a minimum temperature requirement at which the heat pump compressor must still be able to perform. Until this issue is addressed, serious doubts will remain as to whether HPWH efficiency results achieved in the lab will be realized in cold-climate homes.

EPA has begun to recognize the importance of cold-temperature performance by proposing that manufacturers report the compressor cutoff temperature as part of ENERGY STAR® qualification. The [Northwest Energy Efficiency Alliance](#) (NEEA) has gone even further by introducing its [Northern Climate Heat Pump Water Heater Specification](#). It measures unit performance over a range of different ambient and inlet water temperatures. Through its research in the northwest, NEEA has found water-heater ambient temperatures ranging from as low as 34°F (1.1°C) all the way up to 97°F (36.1°C). People can buy water heaters that meet the Northern Climate Specification knowing that the products have been tested under the full range of expected operating conditions. NEEA's work provides DOE with a blueprint for future changes to the federal test procedure.

### European test procedures and climate



In contrast to condensing boilers, the energy label for heat pumps indicates the maximum heating capacity in kW for three different climatic zones within Europe (warm, normal, and cold). To calculate the energy class for Switzerland the climate zone «cold» is used, while for the Netherlands 'normal' and for the south of England 'warm' is used. The default heat supply temperatures are 55 °C and / or 35 °C.

Fig 3.3 The European climatic regions (warm, normal, and cold).

Two major factors occur:

- Humidity assists the performance of a heat pump by increasing the thermal mass passing the evaporator and by transferring some latent heat to the evaporator through condensation. On the other hand, high humidity is not helpful at low temperatures (1 to 2°C) as frost will form on the evaporator. Below 0°C, humidity condenses out and air is relatively dry, so defrosting can be less frequent – although the operating COP will usually deteriorate.
- Frost formation ('frosting') is the formation of a thin layer of ice which becomes a physical barrier to the air flow over the evaporator as well as an insulating barrier that inhibits heat transfer. Simulating performance beyond the point where frosting commences is not usually possible, as a number of non-linear effects come into play, so physical tests under frosting conditions are usually necessary if the product is intended for use in these conditions. Fig. 3.4 shows the climatic regions in Japan with the humidity factors.

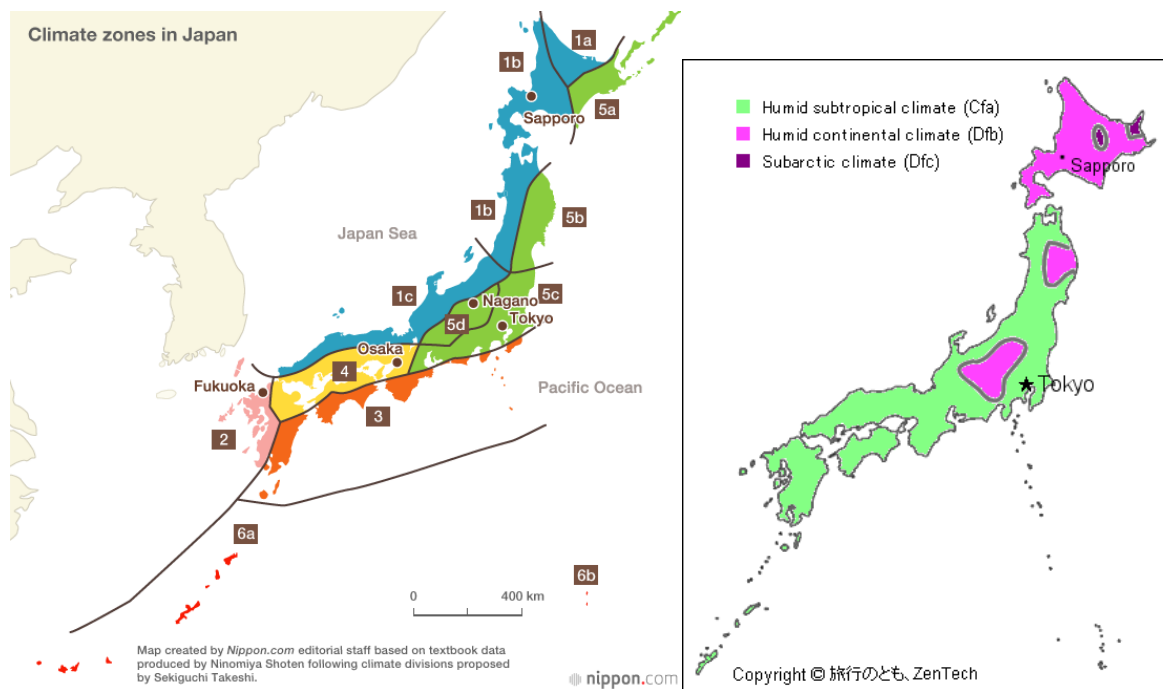


Fig 3.4 Climatic regions in Japan (left) and humidity factors in Japan (right)

### 3.3 Draw Offs and Quantity of hot water usage

Test procedures are defined to register the energy efficiency of a generator by a number of steady state measurements. By the inclusion of a number of tapping loads in a standard, it is possible to:

- Collect data on how the water heater responds to a typical draw, so that this can be used in further calculations or modelling;
- Test the extremes of performance (e.g. how much ‘hot’ water above a specified temperature it can deliver in each draw, and how quickly it can recover to the point where hot water can be drawn off again);
- Simulate performance in actual use.

As hot water use is highly variable (both within a household and across households), there is no guarantee that any given tapping pattern (or patterns) will be statistically representative of actual use in a given population of households even in the one country, let alone between countries.

Thus it is Important for the overall performance and design of a DHW system to test the dynamic performance of the generator by a number of test procedures simulating the actual performance in practice.

This is measured for individual systems by the:

- **Draw efficiency** is the amount of hot water drawn from the tank-type water heater (available to the consumer), at a determined flow rate and before the outlet water temperature drops a certain number of °F/°C.
- **Draw off patterns** over a period of time, often dependent on the amount and type of users

#### Draw efficiency

When using a storage type heater for water heating, 70% of the hot water of the tank’s volume may be drawn before hot water dilutes with the incoming cold water. For example, in a 200 L storage tank, the heater can deliver approximately 140L of hot water (70%).

In the US standard (which no.) the **First Hour Rating** (FHR) is introduced as a measure of the available hot water capacity of the WH (in gallons). According to the test method, hot water (125±15°F) is drawn from the tank as long as the leaving water temperature is 67±2°F higher than the entering water temperature. Once the leaving temperature drops below the prescribed limit, the supply is stopped until the set point of 125±15°F is met again, followed by another draw. Following this procedure, the total water drawn from the tank during one hour indicates the total capacity of the heat pump and electric resistance heaters.

The flow rate when measuring the FHR is a very important condition, as with:

Table 3.2 – Draw Pattern to be used for measuring the First Hour Rating (FHR) in the US standard xxx. (convert gallons/minute to L/min for comparison with the EU and Japan, 1 gallons/min = 3.785 L/min)

Maximum GPM rating greater than or equal to:	and maximum GPM rating less than:	Draw pattern to be used in simulated-use test
0 gallons/minute	1.7 gallons/minute	Very-Small-Usage (Table III.1).
1.7 gallons/minute	2.8 gallons/minute	Low-Usage (Table III.2).
2.8 gallons/minute	4 gallons/minute	Medium-Usage (Table III.3).
4 gallons/minute	No upper limit	High-Usage (Table III.4).

Some standards specify a single flow rate for all draw-offs, while others specify lower flow rates for smaller-volume draws and higher flow rates for higher-volume draws. The flow rate has a significant impact on performance, because higher flow rates will cause more mixing, or ‘de-stratification’ of the water in the tank.

It is important to include and validate the bulk mixing occurring during water draw from the tank. Figure 3.5 represents water velocity streamlines (in m/s) for an adiabatic water tank as the hot water is withdrawn from the top and replenished by cold water entering the tank through the dip tube near the bottom. The bulk mixing happening solely because of “backflow effect” is clear. It is important to note that a number of models ignore this relatively important phenomena, which dominates the natural convection currents but occurs only during water draw events.

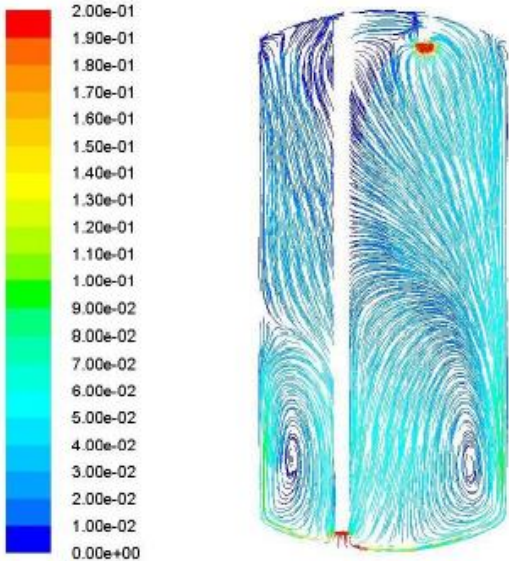


Fig 3.5 Streamline for water flow in the tank during draw (scale shows velocity in m/s) [06] (hot water is withdrawn from the top and replenished by cold water entering the tank through the dip tube near the bottom.)

It is important to understand that different usage patterns can occur in the tank water heater depending on the standard procedure defined as DOE test method. Different usage patterns were selected to investigate the thermal performance of the tank water heater to cover the most common usage patterns from low usage to high usage per the DOE rule making (DOE 2013)[03]. One of the advantages of a wrapped coil tank is that if it is configured correctly, the thermal stratification can be achieved during the heating process, which is desirable for improved performance of water heater. During the charge/discharge process, the supply and recovery water flow can disturb the thermal stratification due to the flow dynamics inside the tank. Backflow represents the phenomena caused by the recovery water entering the tank at low temperature (292 K) which generates the circulation and disturbs the stratified pattern. Since this directly impacts the performance of the water heater, the effect of backflow needs to be accurately quantified at different flow patterns [16].

**Draw off patterns**

In general, physical test standards fall into two groups: those where the DHW HP only heats up the water from cold, and those which involve actual draw-offs of hot water and subsequent reheating.

Simple draw-off sequences (larger volumes at longer time intervals) are also fairly reproducible. There are greater difficulties in reproducing complex sequences of variable draws, especially where the signal for terminating a draw is the temperature of the flow.

The tapping or draw-off schedules represent a major difference between tests worldwide. The range is from no tapping at all (China and Korea), one draw repeated 6 times (Canada and USA), and multiple combinations of tapping schedules and ambient conditions (Japan and Europe). It is not possible to conclude that any of the draw-off sequences in any of the existing test methods is superior to another. Some will reveal different weaknesses in the performance of the water heater (e.g. the ability to reheat after long draws, and whether

reheating occurs at all after short draws) [01].

The most detailed physical energy tests involve all of the following stages (illustrated as a sequence in Figure 3.6, adapted from EN16147):

- A. the heating up period;
- B. the determination of 'standby' (or 'static operation') energy to compensate for heat loss while the hot water is untapped;
- C. the hot water 'tapping' or draw-off sequence;
- D. maximum quantity of water that can be drawn off before the temperature of the flow falls below a specified threshold;
- E. tests to determine the rate of reheat.

Not all test standards include all of these stages, or perform them in the same order. Some standards include multiple sequences of energy tests under different operating conditions, including conditions, which induce frosting on the evaporator.

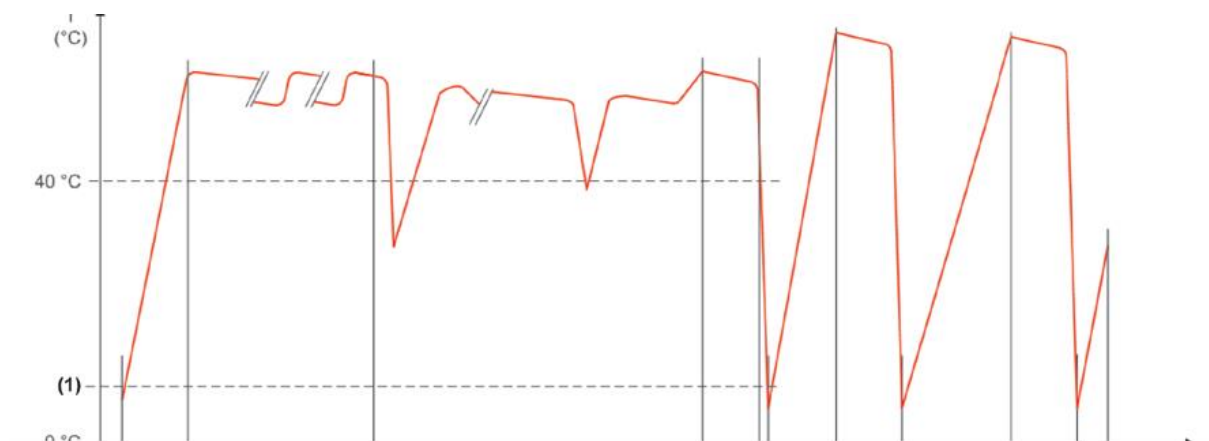


Fig 3.6 Typical stages of DHW HP testing (EN16147) (Temperature in °C y-scale, x-scale time in minutes)

Even detailed draw-off tests covering different daily loads and sequences do not necessarily replicate the hot water use of all households. Research on hot water use generally indicates that it is highly variable from one household to another, and in the same household over time. There is no standard draw-off sequence that could reliably represent hot water use in all countries or even one country for that matter.

At the same time, all hot water use is similar in that it consists of sequences of draws at irregular intervals and of different volumes and flow rates. Therefore, measuring how a water heater performs over one sequence of tasks may allow its performance at other tasks or other ambient conditions to be calculated or modelled. While there are some demographic and climatic drivers for hot water use, there are random elements as well. It is important to consider the performance of the DHW HP over the likely distribution of use, which makes specific draw-off patterns less useful, unless they are used to develop and verify a more flexible global modelling approach.

The main objective in collecting hot water draw data is to create representative profiles to be used in water heater simulations. At its most basic, the draw profile is sometimes thought of as an average daily volume assumed to be constant over the year. Field and lab studies have shown, however, that the control strategies employed by the HPWHs respond differently to different draw patterns. In other words, given the same daily total amount, the exact time and amount of water use across multiple days can dramatically change equipment efficiency. Consequently, if a simulation is expected to produce reasonable performance estimates, it is important to develop typical draw profiles based on the data observed, as was being done in a study by Ecotope in 2015 [10].

### 3.4 Control strategy

The control strategy making a logical use of the possibilities and restrictions of heat pumping technologies can make a great impact in the overall performance of the system. Important factors can be:

- On/off temperature difference of the thermostat
- Control logic, heating the storage water once a day or keeping the storage temperature at required level during the day
- Thermostat setting and location of the thermostat in the storage tank

The first point is dependent on the thermostat itself. By increasing the temperature difference ( $dT$ ) of the thermostat in switching on and off will increase the COP of the Heat Pump Water Heater (studied in 1980 by Kleefkens in the laboratories of Inventum). In fact it lets the stored water get colder and is thus increasing the  $dT$  between condenser and water and decrease the modulation of the heat pump. This is on a larger scale confirmed by the control strategy of heating the stored water only once per day. The project of Rijswijk Buiten (NL) shows a significant difference of 1.0 on measured COP of the DHW Heat Pump between the storage vessel that was heated once a day (COP >3.7) and the storage vessel that was kept on temperature (COP of 2.7). One of the important reasons is that the heat pump has a longer running time and fewer modulations during the heating up of the complete stored water, than with only reheating keeping the stored water at temperature.

The art of a good control of these mechanisms is optimal stratification of the stored water in the tank. This is confirmed by the research by Furbo et.al. [12], where it is shown that with a good stratification in the tank the tank heat losses can be reduced significantly. At the Rijswijk Buiten project losses were observed smaller than 40Wh for a 150 storage tank at 55°C.

Water heaters are now being designed with control logic that can adapt to the pattern of household hot water use. For example, if the controller observes that hot water demand is concentrated at a certain time of day it can adapt reheat times to minimise heat loss or to make use of cheaper electricity rates (assuming that there is a capability for the water heater to have tariff times programmed into it, or to monitor them in real time).

While 'smart' controls may enable a water heater to reheat at times when electricity tariffs are lower use, and so reduce running costs, they complicate energy efficiency testing because the water heater may behave differently after 'learning' the draw-off patterns used in the first stages of a test.

Smart control means a device that automatically adapts the water heating process to individual usage conditions with the aim of reducing energy consumption (or cost);

- 'smart control compliance' (smart) means the measure of whether a water heater equipped with smart controls fulfils the criterion set out in point 4 of Annex IV;
- 'smart control factor' (SCF) means the water heating energy efficiency gain due to smart control under the conditions set out in point 3 of Annex III;
- 'weekly electricity consumption with smart controls' ( $Q_{elec,week,smart}$ ) means the weekly electricity consumption of a water heater with the smart control function enabled, measured under the conditions set out in point 3 of Annex III, expressed in kWh in terms of final energy;
- 'weekly fuel consumption with smart controls' ( $Q_{fuel,week,smart}$ ) means the weekly fuel consumption of a water heater with the smart control function enabled, measured under the conditions set out in point 3 of Annex III, expressed in kWh in terms of GCV;
- weekly electricity consumption without smart controls' ( $Q_{elec,week}$ ) means the weekly electricity consumption of a water heater with the smart control function disabled, measured under the conditions set out in point 3 of Annex III, expressed in kWh in terms of final energy;
- weekly fuel consumption without smart controls' ( $Q_{fuel,week}$ ) means the weekly fuel consumption of a water heater with the smart control function disabled, measured under the conditions set out in point 3 of Annex III, expressed in kWh in terms of GCV;

### 3.5 Heat transfer system

Thermal Stratification impacts the thermal performance of DHW systems<sup>6</sup>.

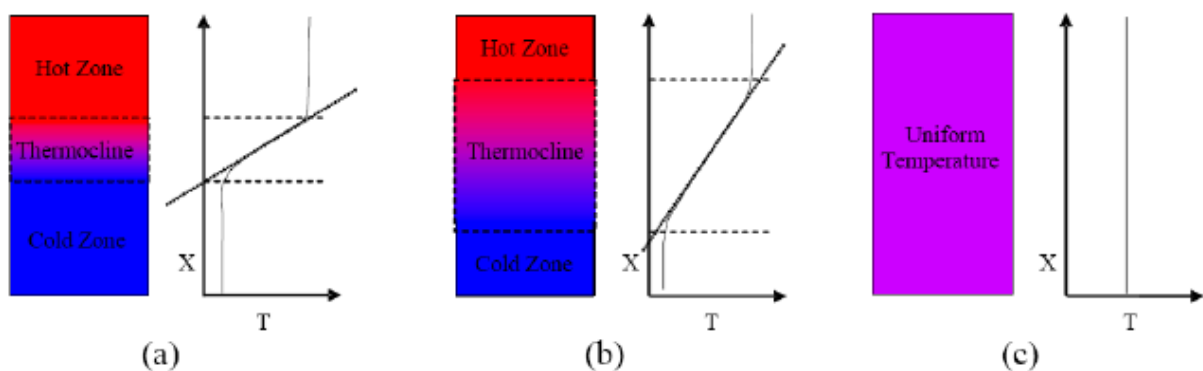


Fig 3.7 – Different levels of stratification within a storage tank with equivalent stored energy (a) highly stratified, (b) moderately stratified and (c) a fully mixed, unstratified storage tank [12]

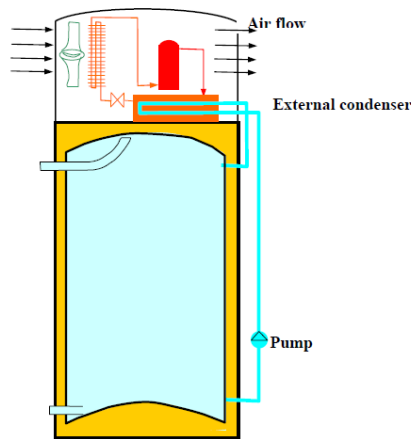
Building of stable thermocline in time and space implies that the mixing should be minimized. Stable thermal stratification or thermocline within the tank can be achieved by various means:

- Heating of vertical walls, which results in the creation of hot thermal boundary layers drawing hot fluid into the upper part of the tank, as with a wraparound condenser.
- Heat exchange between the fluid contained in the tank and that circulating in a heat exchanger carefully placed inside or outside the tank.
- Direct inlet into the tank of hot fluid at suitable heights as with a gas cooler.

The configuration of the condenser has great impact on a stable thermal stratification within the tank. Thermal stratification in the storage tank is also influenced by various parameters such as insulation thickness, flow rate at inlet and outlet, tank inlet and outlet geometry [20]

#### Gas Cooler as external condenser

<sup>6</sup>A high degree of thermal stratification increases the thermal performance of solar hot-water systems because the return temperature to the solar collector is lowered. A lower return temperature to the solar collector will increase the efficiency of the solar collector (Fan, Furbo [12])



Gas cooler can be tube-in-tube heat exchanger or brazed plate heat exchanger. The coolant-to-refrigerant heat exchangers are modelled using a segment-to-segment approach, i.e. dividing refrigerant and coolant channels into numerous segments. In each segment, the model considers heat transfer and pressure drop, as well as the energy balance between the refrigerant and coolant sides. For brazed plate heat exchangers, the refrigerant and coolant side heat transfer correlations were obtained from a manufacturer's product performance data; for tube-in-tube heat exchangers, the heat transfer correlations were obtained from Rousseau [27]. The gas cooler model can simulate any flow patterns, i.e. counter flow and parallel flow.

Fig 3.7- External condenser

For the gas-cooler configuration in a CO<sub>2</sub> HPWH, the water circulation rate between storage tank and the heat exchanger is an important parameter influencing performance. Water temperature stratification has been considered an important aspect especially for a CO<sub>2</sub>-based HPWH and the water flow rate through the pump dictates the achievable stratification. It can be observed that even though the top of the tank was less sensitive to the circulation rate (node 0), for the middle (node 5) and bottom (node 9) of the tank, the temperature profile is quite different for two flow rates. As mentioned earlier that because higher stratification favours better Unified Energy Factor and COP, a relatively lower circulation rate is recommended. However, if the flow rate is too low, it can adversely affect the performance as the water will be over-heated at the exit of gas-cooler, which deteriorates the cycle performance [06].

### Wrapped Tank Condenser

A wrapped-tank condenser model was developed specifically for this investigation, using a segment-to-segment modelling approach. The flow-pattern-dependent heat transfer correlation published by Thome (2003) was used to calculate the condenser two-phase heat transfer coefficient. As for the evaporator, the pressure drop correlation published by Kedzierski (1999) was used to model the two-phase pressure drop. The heat transfer between the refrigerant and water is calculated by considering the forced convection at the refrigerant-side, tube and water tank wall conductance, and water-side natural convection.

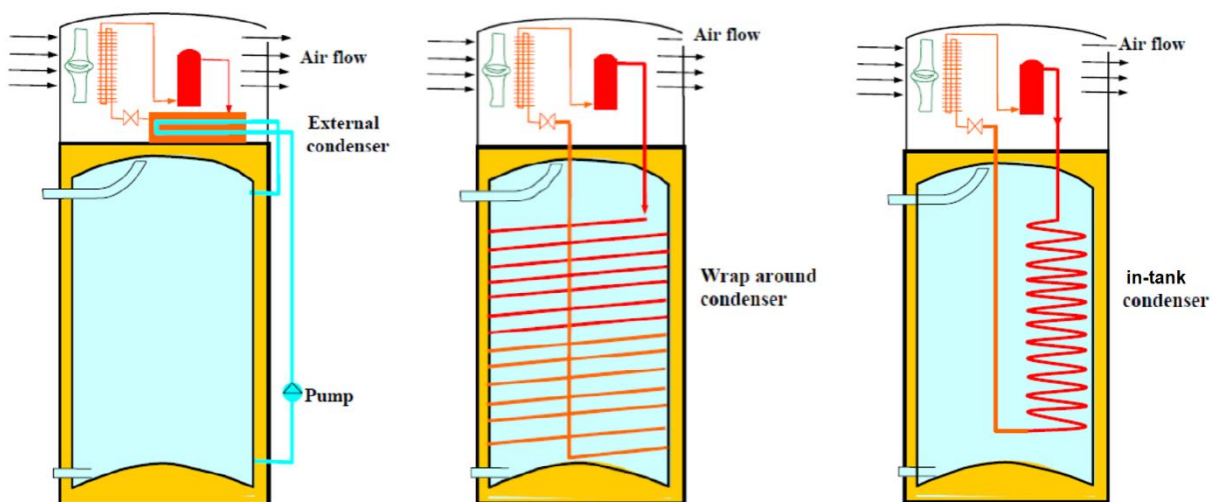


Fig 3.8 Condenser configurations with a storage tank. External condenser, wrapped tank condenser, and in-tank condenser.

The coil model simulates temperature and pressure variations in mini-segments along the refrigerant flow direction, and interacts with the node temperatures of a transient, stratified water tank model.

Charging/discharging of the wrapped coil water tank of the heat pump water heater is an important process, which directly affects the performance of the system. The charge/discharge process significantly affects the thermal stratification in the tank maintained during the standby period. As cold recovery water enters the tank and the supply hot water is discharged from the tank, the water circulation disturbs the thermal stratification and enhances the mixing thus reducing the tank water temperature.

**In tank condenser**

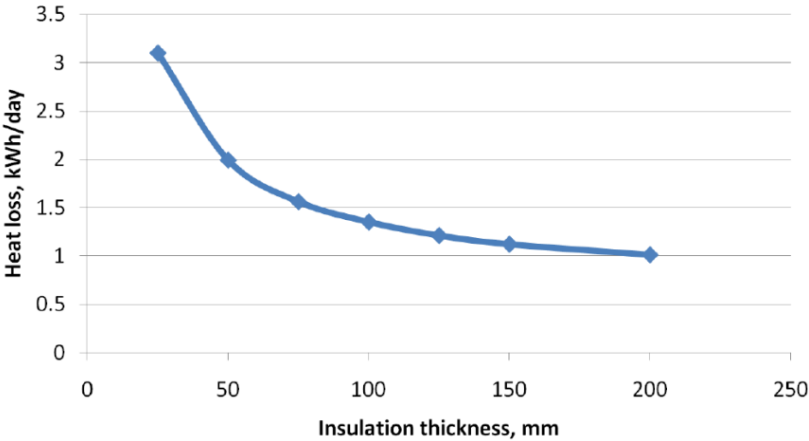
Although in Figure 3.9 illustrated as a condenser on the top of the storage tank the condenser in the majority of the Heat Pump Water Heaters is positioned at the bottom of the tank.

**Auxiliary Heat Source** DHW HPs often have an auxiliary heat source, usually an electric resistance element, which can supplement the vapour compression cycle during the initial heating of water from cold, during periods of high hot water demand or when the vapour compression cycle is unable to operate effectively (e.g. under frost or very low external temperature conditions). Such DHW HPs are sometime called ‘hybrid’ models.

The operation of the auxiliary heater may be automatic or manually controlled. For user-selectable heat sources, the setting for the tests is not always clear. For example, it may be possible to switch the element on for the tests of hot water delivery capacity and reheat times, but switch it off for the tests of energy-efficiency. While this would be misleading, not all test standards explicitly prevent this anomaly.

**3.6 Heat losses of the storage tank**

The in-use energy efficiency of a DHW HP depends on its ability to retain stored heat as well the incremental energy to heat water from cold. Some test procedures measure the energy required to maintain the stored hot water at the maximum setting of the thermostat or temperature controller when no water is drawn off. This is



influenced by both the heat loss of the tank and the energy-efficiency of the heat pump at what is usually its least efficient operating point.

Losses of the storage tank are part of the testing procedure. Typical losses vary from 30 W to 200 W continuously, resulting in 270-1800 kWh/yr extra heating demand for the generator.

Fig 3.8 – Storage losses as a function of the tank insulation thickness

For several sizes of storage vessels, the EU has classified values as in table 3.3 related to the Energy Label:

Table 3.3 – Hot water storage loss factor

Storage losses [W]		Storage vesselsize [litr]		
		80	150	300
EU E-label				
A+/A	very good	24	29	36
A/B	good	33	40	50
B/C	acceptable	46	56	70
C/D	average	65	78	98
D/E	below average	81	98	122
E/F	poor	105	127	160
F/G	very poor	127	155	194

### 3.6 Product Classification and Configuration

Water heaters may be sold as unitary units or as assemblies of components. For example, in the case of heat pump water heaters (HPWH) this can include:

- unitary (refrigeration unit and water storage tank in the one cabinet)
  - split – heat pump connected to tank by refrigerant lines, condenser inside water tank
  - split – heat pump connected to tank by water lines, condenser housed in same cabinet as evaporator.
- This configuration may be designed as:
- single pass ('one time') – water heated to desired temperature in one pass;
  - multi-pass ('circulated') – water heated to desired temperature in stages.

The way in which DHW HPs are defined varies significantly between standards (see Appendix A). This shortlist is overlooking DHW HPs, like:

- Double function heat pumps for space heating and DHW
- Booster Heat Pumps
- Fresh Water Heat Pumps
- Solar – heat pump combinations

This means that products which are grouped together for testing under one standard may need to be separately tested under a second standard, because of some design difference that may not even be defined under the first standard. Furthermore, a product type defined in one standard may not even be testable under other standards, because there is no provision for them. For example, the European Standard EN16147 does not appear to provide for the testing of a unitary DHW HP designed to be installed outside, whereas this product type is common in Australia.

Important aspect is the configuration of the DHW HP where the heat exchanger in relation to the storage tank can be normative for the performance of the DHW HP. Oakridge in the US has done a number of tests with different refrigerants, which showed a higher COP for an external plate heat exchanger than for a wrap-around heat exchanger [06].

**Capacity** Some DHW HPs may be defined as 'commercial' in that they can provide larger quantities of hot water or at a higher temperature. However, the criteria are not always clear. The US AHRI standard 1301 defines a commercial heat pump as one where the input capacity does not exceed 50 kW, and which is not covered by US Regulations 10 CFR Part 430. China Standard GB/T 21362–2008 defines a 'Commercial & Industrial' DHW HP as one with 'nominal heating capacity of 3'000W and above'. Many DHW HPs sold to the residential market have a far greater heating capacity than this limit. Furthermore, some domestic DHW HPs can be easily adapted for commercial use by adding multiple storage tanks.

Some DHW HPs are also designed to provide hot water for space heating purposes (under-floor coils or radiators) as well as sanitary hot water. Some standards allow DHW HPs to be tested while in one or other of these

operating modes, but to date there is no standard for testing a DHW HP that is simultaneously serving a domestic water heating load and a space heating load.

### 3.7 Sound levels

[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 eco-design requirements for water heaters and hot water storage tanks

BENCHMARKS FOR SOUND POWER LEVEL (LWA), OUTDOORS, OF HEAT PUMP WATER HEATERS WITH:

- a. rated heat output  $\leq$  6 kW: 39 dB;
- b. rated heat output  $>$  6 kW and  $\leq$  12 kW: 40 dB;
- c. rated heat output  $>$  12 kW and  $\leq$  30 kW: 41 dB;
- d. rated heat output  $>$  30 kW and  $\leq$  70 kW: 67 dB.

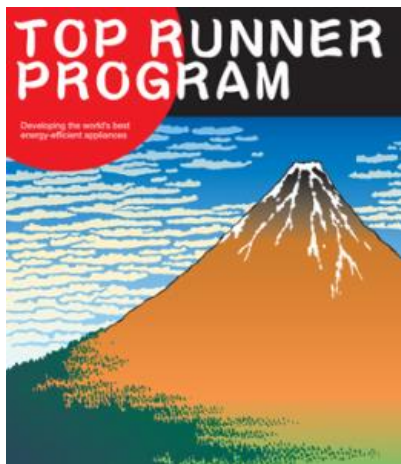
## 4. Legislative requirements and quality labels

Test standards are used in support of MEPS and Energy Labelling legislation (e.g. Ecodesign (Europe), TOP Runner (Japan), China Energy Label (CEL), Energy Guide labels in North America) and of various voluntary programs (e.g. European ECO label, Energy Star).

### 4.1 Asia

The main markets considered here are Japan, South Korea and China, all having a number of quality labels.

#### 4.1.1 Japan



The centrepiece of Japan's appliance and equipment efficiency programme is the Top-Runner scheme.

The [Top-Runner scheme](#), which sets the targets for the weighted average energy efficiency of each manufacturer's and importer's shipments in predefined product categories to the level of the most energy-efficient model in each category on the current market. Today's best model sets tomorrow's standards.

Manufacturers and importers of energy-consuming equipment are obliged to indicate the energy efficiency of their products.

Fig 4.1 – Top Runner label for Japan

These new labels indicate, with a symbolic mark, the product models' percentage fulfilment of the Top-Runner efficiency standards. MITI, by agreement with the U.S. Environmental Protection Agency, also uses the Energy Star endorsement label (Figure 4.1) for office equipment. The products concerned are personal computers, displays, printers, facsimile and copying machines, scanners, and multi-function devices. The Japanese and U.S. programmes maintain identical product specifications, and manufacturers which join one country's programme enjoy privileges in the other country's programme.

- The Top Runner sets the standard but takes into account the limits of future potential improvements: standard setting takes into account the potential for technological innovation and diffusion.
- Differentiated standards are set based on a range of parameters that affect energy efficiency within product groups. These parameters include function (e.g. copying machines—number of copies made per minute; TV sets—whether a recorder is included or not etc.), size (e.g. refrigerators—internal volume; TV sets—size of screen), weight (e.g. passenger vehicles), types of technologies used (e.g. refrigerators—refrigeration method), fuel used (e.g. passenger vehicles) and other practicable differentiations.
- Compliance with the standard is evaluated by corporate average product sales. In order to comply with the standards, producers must make sure that the weighted average efficiency of the products they sell in a target year achieves the standards. Therefore not all of a manufacturer's products have to meet the target, but the average of all products has to. This flexibility enables producers to provide a wide range of models to meet the market demand while guiding the overall market to higher energy efficiency.
- Compliance with the standard is rewarded: efficient machinery and equipment has so far been promoted with a labelling programme. The label includes an expected electricity bill and a 5-star rating to represent the relative position of a product in the market with respect to energy-saving performance.
- Non-compliance with the standard is penalised: in case of non-compliance the Top Runner Programme uses a 'name and shame' approach, putting the brand image of companies at risk as opposed to their profit.

## 4.1.2 Korea

With the increase in the distribution of energy efficient products, the government of Korea is enforcing the Minimum Energy Performance Standard (MEPS), which establishes the mandatory usage of energy efficiency standard labels (Level 1~5). Under the [Energy Efficiency Standards & Labeling Program](#) run by KEMCO, high energy consuming products are rated from 5 to 1 grade. The Energy Efficiency Label (from 5 to 1 grade) should be attached to products. Production and sales of products that fall below the MEPS are prohibited. All domestic manufacturers and the importers must keep this program. This program is Korea's core energy efficiency management scheme. As of 2010, 19,000 models of 24 different product types were registered including, next to Heat Pump Water Heaters, refrigerators, air conditioners, washing machines, light equipment, and three-phase inductor motors. Each year, 150 million products are sold under the MEPS or energy efficiency standard program.

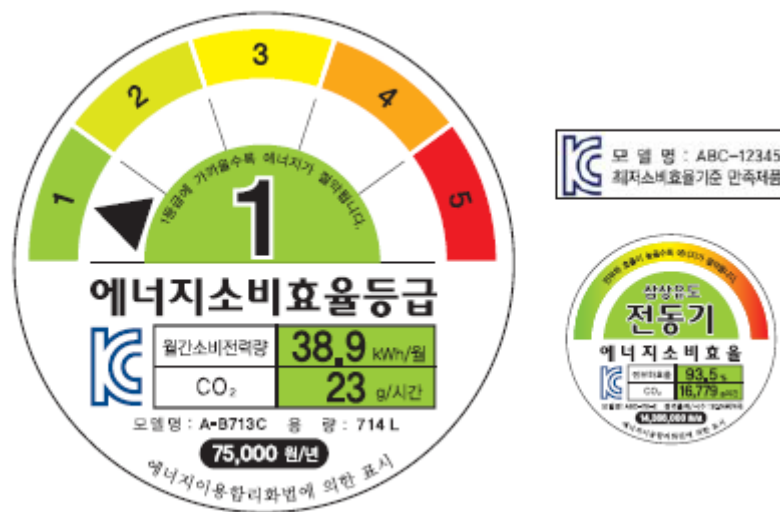


Fig 4.2 – Energy Efficiency Label for products in Korea

Referring to an obligatory energy efficiency standard that restricts the production and sale of low efficiency products that have not reached a certain efficiency level or constant power consumption level and drastic energy conservation, and in case of a violation, a fine of not more than 20 million won is imposed.

The Energy Efficiency Label and Standard Program enables consumers to identify high efficiency energy efficiency products easily by mandatory indication of energy efficiency grade from 1st to 5th grade, mandatory reporting and applying MEPS.

1. According to the energy efficiency or the quantity consumed of the product, the product is required to indicate an energy efficiency grade from 1st to 5th grade
2. Mandatory reporting of energy efficiency grade by manufacturers (importers)
3. Production and sales of products that fall below the 5th grade is prohibited (Applying MEPS)

Peak shaving is seen as very important to reduce energy usage. The midnight power equipment of the Korea Electric Power Company (KEPCO) distributes the electric power demand concentrated in a specific time zone, increases demand in the late night (23:00 pm-9:00 am) where electricity usage is small, to supply electricity in late-night time to efficiently use it. It refers to equipment that produces heat, hot water or ice and uses it for hot water supply, heating or cooling. The centre conducts demonstration tests and post-examinations tests on the midnight power equipment of Korea electric power.

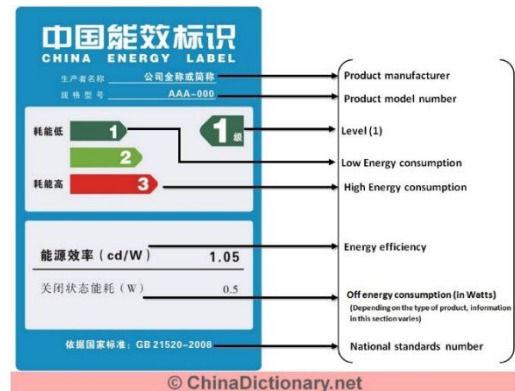
Heat Pump Water Heaters are contributing to power load levelling by using late-night electric power when used in combination with cold storage system.

The Korea Refrigeration & Air-conditioning Assessment Center conducts the above two certification tests and issues the certificate to manage the efficiency of the heat pump water heater.

### 4.1.3 China

The China Energy Label (CEL) is an energy consumption label for products in China, similar to the European Union energy label. Manufacturers of specified electronic devices are obligated to attach a CEL label to their goods to inform China-based consumers of the product's energy efficiency. The label includes the product's energy efficiency class (1-5) as well as information regarding its energy consumption.

Fig 4.3 – China Energy Label



The CEL shows the level of energy consumption and, thus, the energy efficiency of a product. The CEL aims to encourage customers to buy energy efficient products. The target to increase energy efficiency and the acceptance of Chinese consumers towards energy efficient products is highly important, since China is the world's largest energy consumer.

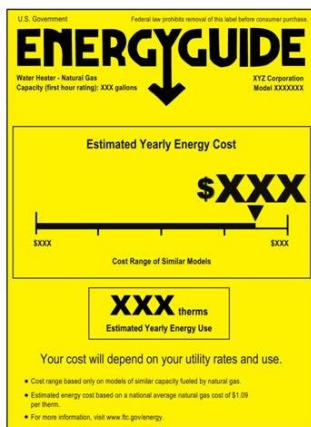
Applications has to be filled in at the [China Energy Label Center](#)(CELC) (add footnote), which is the main authority for CEL-classification.

Following legal provisions from the Energy Conversation Law, and support from the Product Quality Law and Legislation on Certification & Accreditation, the provisions and implementations were solidified in the Administration Regulation on Energy Efficiency Label mandate within this new law.

The mandatory energy efficiency label identifies a product's efficiency on a scale of 1 to 5, with one being the least efficient and 5 the most. Labels must be present at the point of sale of any product covered by the mandate. Manufacturers are required to submit product performance information to CELC but allowed to print the label on their own products and product literatures.

The mandatory energy efficiency label identifies a product's efficiency on a scale of 1 to 5, with one being the least efficient and 5 the most. Labels must be present at the point of sale of any product covered by the mandate. Manufacturers are required to submit product performance information to CELC but allowed to print the label on their own products and product literatures.

### 4.2 North America



All water heater types with a MEPS listed are required to have an attached label at the time of sale to the final consumer. The label contains a graphic display of the relative projected annual energy consumption of the water heater relative to water heaters with similar capacity based on the test procedure. The label also displays an estimated annual energy cost based on national average energy prices. The requirements for size, colour, contents, etc. of the label are fully described in 16CFR 5—Rule Concerning Disclosures Regarding Energy Consumption and Water Use of Certain Home Appliances and Other Products Required Under the Energy Policy And Conservation Act (“Appliance Labeling Rule”).

Fig 4.4 sample EnergyGuide label for a gas storage water heater

[ENERGY STAR](#)<sup>®</sup> is the government-backed symbol for energy efficiency, providing simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions. Thousands of industrial, commercial, utility, state, and local organizations—including more than 40 percent of the Fortune 500<sup>®</sup>—rely on their partnership with the U.S. Environmental Protection Agency (EPA) to deliver cost-saving energy efficiency solutions. Ninety-percent of American households recognize the ENERGY STAR, making it one of the most widely recognized consumer symbols in the nation. EPA ensures that each product that earns the label is independently certified to deliver the quality, performance, and savings that consumers have come to expect. It's that integrity that led Americans to purchase more than 300 million ENERGY STAR certified products in 2016.



For ENERGY STAR products, EPA is responsible for setting product performance levels. EPA also oversees third-party certification and verification testing. Across the more than 75 product categories, EPA has demonstrated accessibility and transparency in the implementation of the ENERGY STAR products program. EPA also is responsible for the ENERGY STAR New Homes, Commercial, and Industrial programs, including ENERGY STAR Portfolio Manager.

For ENERGY STAR products, DOE develops test procedures for ENERGY STAR products and contributes to verification testing of appliances and equipment. DOE also sets minimum efficiency standards for some products through a regulatory process. EPA and DOE work closely to share data and analyses, synchronize timing, and coordinate requests to industry in the development of both the voluntary ENERGY STAR specifications and the DOE minimum efficiency standards. DOE is also responsible for Home Performance with ENERGY STAR.

The Water Heater Key Product Criteria can be found on the [ENERGY STAR](#) website

Efficiency and performance for ENERGY STAR certified water heaters may be evaluated using two different methods. A water heater can be certified as ENERGY STAR by meeting Energy Factor (EF), Standby Loss, and/or Thermal Efficiency criteria or by meeting Uniform Energy Factor (UEF) criteria. Although these performance metrics are different, certification as ENERGY STAR by either method requires equivalent efficiency. Consumers should not directly compare EF values to UEF values.

Solar water heaters must meet minimum Solar Energy Factor criteria to be certified as ENERGY STAR.

The test procedures for these water heaters are defined in the Energy and water conservation standards 10 CFR 430.32 and further discussed under [Appendix E to Subpart B](#) of Part 430 - Uniform Test Method for Measuring the Energy Consumption of Water Heaters.

The Energy Star label and symbol are administered and promoted in Canada by [Natural Resources Canada](#) and are registered in Canada by the United States Environmental Protection Agency.

ENERGY STAR Canada is a voluntary partnership between the Government of Canada and industry to make high efficiency products readily available and visible to Canadians.

Natural Resources Canada (NRCan) formally enrolls manufacturers, retailers and other organizations as Participants in ENERGY STAR Canada. Participants help promote ENERGY STAR and ensure ENERGY STAR certified products are prominent and readily available in the marketplace and to Canadian consumers. NRCan administers and promotes use of the ENERGY STAR name and symbol in Canada under an agreement with the U.S. Environmental Protection Agency (EPA). Canada became an international partner in the program in 2001.

NRCan works closely with the EPA to develop ENERGY STAR technical specifications for products. It also develops Canadian specifications for certain ENERGY STAR certified products.

ENERGY STAR is one of three tools that consumers, governments and businesses use to advance energy efficiency

in Canada:

- Canada's Energy Efficiency Regulations set minimum energy performance standards for energy-using products.
- EnerGuide is Canada's energy-efficiency labelling program and rating system for major appliances, room air conditioners and some heating and ventilating equipment.
- The ENERGY STAR symbol identifies products that have met or exceeded technical specifications for high efficiency.

The ENERGY STAR name and symbol are administered and promoted in Canada by Natural Resources Canada and are registered in Canada by the United States Environmental Protection Agency.

### **EnerGuide in Canada**

EnerGuide is the official mark of the Government of Canada for its energy performance rating and labeling program for key consumer items—houses, light-duty vehicles, and certain energy-using products.

The information provided by EnerGuide allows consumers to compare different models with confidence. The data may be a rating number based on a standard measure or a verified average of energy consumption. Energy efficiency helps Canadians save energy, lower utility bills and reduce our impact on the environment. EnerGuide works in concert with Canada's Energy Efficiency Regulations and the ENERGY STAR® Canada program to promote energy efficiency in the Canadian marketplace. The ENERGY STAR name and symbol are administered and promoted in Canada by Natural Resources Canada and are registered in Canada by the United States Environmental Protection Agency.

### **The EnerGuide label**

The distinctive EnerGuide label is a familiar sight to most Canadians. They see it when shopping for new appliances, look at the literature for a new furnace or read the fine print on a light bulb package. The EnerGuide label lets Canadians know how much energy a product uses and how that compares to similar models.

EnerGuide label for appliances

There are main information displayed on the label

1. Annual energy consumption of the model in kilowatt hours ( kWh)
2. Energy consumption indicator, which positions the model compared with the most efficient and least efficient models in the same class
3. Type and capacity of models that make up this class
4. The model number

The EnerGuide label is mandatory for clothes dryers, clothes washers (including integrated washer-dryers), dishwashers, freezers, electric ranges, cooktops and ovens, refrigerators, refrigerator-freezers and wine chillers room air conditioners. It is voluntary for central air conditioners, furnaces (oil-, gas- or propane-fired), air-source heat pumps, gas fireplaces and water heaters.

The mandatory EnerGuide label can take the form of an adhesive tag, a flap tag (similar to a sticky note) or a hang tag. The voluntary EnerGuide label is usually presented as a graphic in product literature. Often products (such as appliances and room air conditioners), that are regulated and carry the EnerGuide label are also ENERGY STAR certified models. In these cases, the ENERGY STAR symbol will appear at the bottom of the EnerGuide label.

EnerGuide label for appliances

There are five main items displayed on the label

1. Annual energy consumption of the model in kilowatt hours ( kWh)
2. Energy consumption indicator, which positions the model compared with the most efficient and least efficient models in the same class
3. Type and capacity of models that make up this class
4. The model number
5. The ENERGY STAR symbol

### 4.3 Europe

Within the framework of the European ErP Directive 2009/125/EC (Energy-related Products Directive), also known as the Ecodesign Directive<sup>7</sup> (EU, 2013a), the EU adopted new requirements for the ecological design and labelling of energy-related products. Boilers and combined heaters (including heat pumps) and hot water heaters (including domestic hot water heat pumps) are affected. As of September 2015, all manufacturers are obliged to comply with the minimum requirements contained in the Ecodesign Directive. New equipment placed on the European market must meet these requirements.

The Ecodesign and Energy Labelling Regulations for space and water heaters were published in 2013 and for solid fuel boilers in 2015. The regulations establish minimum requirements and an energy labelling scheme for the products in their scope. The European Commission has published guidelines to help relevant stakeholders, including industry and public authorities, to implement the Regulations in practice. They summarise the most relevant information from the regulations to give SMEs an introduction to the subject matter and answer the most common questions.

The energy label is a benchmark for the end-consumer to see how economical, environmentally friendly and/or energy saving the product is. The success of the label has been a driver for innovative industry developments, with most of the products being in the top classes (A+++, A++, A+) today. Under the current legislation, a maximum A++ on the product label is applicable. Figure.6 shows a version of the energy label<sup>8</sup> for domestic hot water heat pumps. The symbol in the upper left corner of the energy label indicates whether it is a hot water heater or hot water storage. The water tap symbol stands for the water heater, a container with wave lines symbolizes the hot water storage tank. The Ecodesign and energy labelling for water heaters is defined under the Commission Regulation [No 814/2013](#).

The following information shall be included in the European energy label for a domestic hot water heat pump:

- I. supplier's name or trade mark;
- II. supplier's model identifier;
- III. the water heating function, including the declared load profile expressed as the appropriate letter in accordance with Table 3 of Annex VII;
- IV. the water heating energy efficiency class under average climate conditions, determined in accordance with point 1 of Annex II; the head of the arrow containing the water heating energy efficiency class of the water heater shall be placed at the same height as the head of the relevant energy efficiency class;
- V. the annual electricity consumption in kWh in terms of final energy and/or the annual fuel consumption in GJ in terms of GCV, under average, colder and warmer climate conditions, rounded to the nearest integer and calculated in accordance with point 4 of Annex VIII;
- VI. European temperature map displaying three indicative temperature zones;

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<sup>7</sup>[EU Ecodesign-Richtlinien Boiler: 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.](#)

<sup>8</sup>[www.gebaeudeklima-energieetikette.ch/typo3/index.php?id=11](#)

- VII. the sound power level L<sub>WA</sub>, indoors (if applicable) and outdoors, in dB, rounded to the nearest integer;
- VIII. for heat pump water heaters able to work only during off-peak hours, the pictogram referred to in point 6(d)(11) of this Annex may be added.

The design aspects of the label for heat pump water heaters shall be in accordance with point 6 of this Annex. By way of exception, where a model has been granted an ‘EU Ecolabel’ under Regulation (EC)

The hot water heater label includes the energy class on a scale of A to G, or A+ to F. This indicates the “water heating efficiency class” at a specific tapping cycle (draw-off profile, e.g. “L” symbol). The larger the tapping profile, the higher the required energy factor a model must meet to attain a given rating. In the case of hot water storage, the storage volume in liters (L) and the heat retention losses in watts (W) at a certain water and ambient temperature are also declared, i.e. the energy lost to keep the water warm. Table 3.1 shows the efficiency classes for heat pump water heaters (EN 16147, 2011; EU, 2013b; SEAD, 2013).

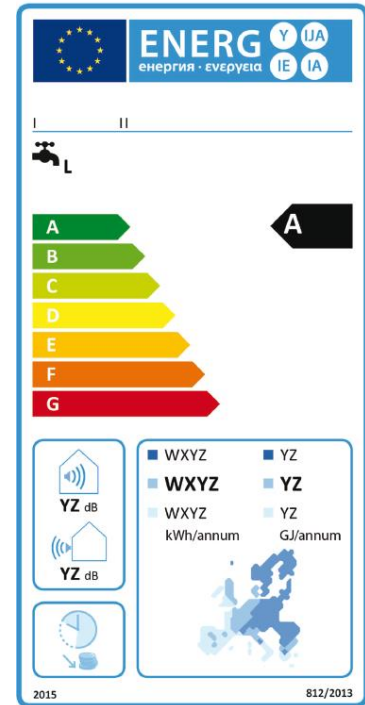


Figure 4.6: European energy label for a domestic hot water heat pump

Table 4.1: European water heating efficiency classes for heat pump water heaters (EN 16147, 2011; EU, 2013b; SEAD, 2013).

Draw-off profile	Efficiency required to achieve this rating									
	G	F	E	D	C	B	A	A+	A++	A+++
M	<27%	≥27%	≥30%	≥33%	≥36%	≥39%	≥65%	≥100%	≥130%	≥163%
L	<27%	≥27%	≥30%	≥34%	≥37%	≥50%	≥75%	≥115%	≥150%	≥188%
XL	<27%	≥27%	≥30%	≥35%	≥38%	≥55%	≥80%	≥123%	≥160%	≥200%
XXL	<28%	≥28%	≥32%	≥36%	≥40%	≥60%	≥85%	≥131%	≥170%	≥213%

Source : EC (2013) Applies to packaged water heaters under average EN 16147 climate conditions (Table 8)

The A+ to A+++ classes can only be reached by water heaters using renewable energy sources, i.e. either heat pump water heaters or solar water heaters. The energy efficiency classes above A are defined such that the classes A+/A++/A+++ correspond to a contribution of 35%/50%/60% of renewable energy sources to energy consumption, compared to the efficiency class A (SEAD, 2013).

In addition, the climate conditions and the noise levels (in dB) from internal and external components of the heat pump are shown (SEAD, 2013). A pictogram shows the tapping profile on which the HPWH was tested (e.g. a single tap for a low load, a series of taps, showers and a bath for a large load). The annual electricity consumption (in kWh/annum and GJ/annum) for the average, warmer and colder climate conditions is also stated together with the map of Europe. An indication is given whether the HPWH is suited to operate with off-peak tariffs.

In order to estimate the Ecodesign suitability of domestic hot water heat pumps on the Swiss market, their energy efficiency was determined at the heat pump test Centre WPZ in Buchs (WPZ, 2013) according to the Ecodesign rules and compared with the requirements for market approval.

The test conditions of the ErP guideline differ slightly from the EN 16147 measurement. In particular, the air source temperature is 20°C for indoor installations instead of 15°C. The measurements of the WPZ showed that the increase in the source temperature from A15 to A20 results in about 10% higher COP values (Eschmann 2015). The average measured COP values were 3.36 (at 20°C) and 2.89 (15°C) during the reporting year 2015 measured according to EN 16147. A total of 16 heat pumps were measured. As noted by (Eschmann, 2015) the Ecodesign requirements as a whole do not pose a real obstacle to the market approval in Switzerland concerning hot water heat pumps. Table 3.2 shows the required COP values of hot water heat pumps to meet the EU energy

label (Eschmann, 2014). The energy efficiency classes refer to the complete efficiency of the heat pump device (electricity production is assumed to have 40% efficiency, EU mix).

Table 4.2: Required COP values of hot water heat pumps to achieve the EU energy label (Eschmann, 2014).

Zapfprofil	S	M	L	XL	XXL
Entnahmemenge	2.1 kWh	5.8 kWh	11.7 kWh	19.1 kWh	24.5 kWh
Speichervolumen	-	<150 Liter	150 – 249 Liter	250 – 400 Liter	>400 Liter
COP für Gütesiegel	-	2.60	2.60	2.60	2.60
A+++ (ab 2017)	90% (2.25)	163% (4.08)	188% (4.70)	200% (5.00)	213% (5.33)
A++ (ab 2017)	72% (1.80)	130% (3.25)	150% (3.75)	160% (4.00)	170% (4.25)
A+ (ab 2017)	55% (1.38)	100% (2.50)	115% (2.88)	123% (3.08)	131% (3.28)
A	38% (0.95)	65% (1.63)	75% (1.88)	80% (2.00)	85% (2.13)
B	35% (0.88)	39% (0.98)	50% (1.25)	55% (1.38)	60% (1.50)

## 5. Conclusions

There is a great number of test methods for heat pump water heaters in use in different regions of the world, with major differences between them. In an ideal form of harmonisation, testing authorities in each economy would be able to take the results from any of the existing HPWH tests, and use a simulation model to predict what the results would be if the same model were physically tested to their own standard.

Many of the test procedures discussed seem to focus mainly on air source DHWHPs, being the main stream of applied DHW HP's, while there is a large number of alternative heat pump technologies supplying domestic/sanitary hot water. For these there are sometimes no standardized test procedures available or if available acknowledged at international level. As it is important that innovative solutions find their right place in the market, this challenge needs to be addressed. It concerns a range of products such as: multi-function heat pumps, hybrid heat pumps, fresh water heat pump systems, booster heat pumps, combination of solar and heat pumps, extended smart storage systems, larger than 50/80 kW systems, cascade heat pumps, etc.

Another challenge is to harmonize the nomenclature of systems, then go into a clear definition of performance.

What are the next steps towards harmonization?

A set of guidelines can be developed for harmonisation;

- Scope of testing procedure
- Major objectives of the testing procedures (what parameters are to be established)
- Identification of similarities among different procedures.
- Level of complexity/duration of the test procedure
- Scalability of the procedure to smaller vs. larger storage tanks
- Applicability of various technologies (electric, gas fired, heat pump, tankless etc.)

For the existing test procedures for air source heat pumps, given the extent of the differences, it is not considered likely that the standards bodies and energy program regulators in different countries would agree adopting a common standard, without a gradual process of confidence-building and harmonisation. There is some support among global manufacturers who export widely, having commercial interest in reducing the amount of product testing required for each market. For some manufacturers (including global suppliers), differences in methods of test are low on their concerns. Is it of greater commercial interest that the local standards in their export markets shows their products in a good light, and that government support in those markets (e.g. through regulation or direct cash incentives) favours HPWHs.

Even the home economies of these manufacturers may wish to retain their own standards as local standards bodies and regulators have a major investment in the existing methods of test. Although some are investigating possible changes, it is in the context of building on what they already have. The range of ambient conditions and draw-off schedules developed for different standards attempt to replicate local conditions and user behaviour. They have also evolved to reflect the predominant types of product preferred in the local markets, and in some cases do not cover the testing of other configurations.

The ISO Commission ISO/TC 86/SC 6/WG 12 on Heat pump water heaters is working on (published in August 2018) the ISO Draft HPWH-19967-Part1 and Part2. The draft Standard of Part 1 specifies test conditions and test procedures for determining the performance characteristics of air source heat pump water heaters for hot water supply with electrically driven compressors with or without supplementary electric heater and connected to or including only one hot water storage tank.

For single mode DWH testing, the key to harmonisation is a set of basic tests, which might be similar (but not identical) to the most common test conditions currently in use. A proposal of possible harmonized basic test

conditions would be

- Low-temperature test condition of 7°C DB/6°C WB is already included in the European, Japan and Korea (draft) standards, and would be consistent with one of the conditions in the AS/NZS standard (<10°C);
- Water temperature of 10°C for the above test;
- Warm-temperature test condition of 20°C DB/19°C WB – this is already included in the USA, Canada, and China tests, and would be consistent with one of the conditions in the AS/NZS standard (18 to 20°C);
- Water temperature of 15°C for the above test;
- For models designated as suitable for use in frost conditions, a test at 2°C DB/1°C WB (this designation should be part of the Product Classification system);
- For models designated as suitable for warm and humid climate conditions, a test at about 30°C and high humidity.

No draw-off test would be necessary at the above test conditions – only a heat-up test and either a static operation test (in which the compressor is allowed to run to cover heat loss from the tank) or a cool-down test (in which the compressor is switched off and the tank allowed to cool).

The data from the basic test would be used in a simulation method, which could be developed as part of the ISO test or as a separate document. The product parameters would be entered into a model. To the extent that this method required information about a HPWH's refrigeration system or control strategy, it would be restricted to data that could be observed or established through physical tests (which would form part of the basic test suite for certain product types). More complex modelling options may also be included.

It is understood that the ISO Technical Committee C86/SC6, which will be developing the HPWH test, is yet to decide whether to only cover the testing of HPWHs serving a Domestic Hot Water task ("single mode DHW testing"), or also those capable of serving a space heating task as well – either while in one or other modes, or both modes simultaneously. At present, only EN 16147 and the draft KS standard refer to the possibility of dual-mode HPWHs, and EN16147 only provides for the testing of such units in DHW mode. This provides an opportunity for the ISO to develop both a single mode Space Heating test, and a dual-model (space heating and hot water) test, and have them adopted as default international tests.

Considerable work remains to be done to develop simulation models and methods of acceptable accuracy. Some of the issues to be addressed are identified in Appendix C, though as this analysis is based on only a handful of physical tests, the findings are only preliminary.

Characteristics	Country	Organisation	Label/program	Label	Test standards
Voluntary Minimum Energy Performance Standard	United States	DOE			CFR 430
	Canada	Natural Resources Canada			CAN/CSA-C745-03 (R2014)
	Japan	METI	Top Runner Program		JIS C 9220-2011
	South Korea				
	EU (27 countries)	EU Commission	Eco - design		EN 16147
	Switzerland	Fachvereinigung Wärmepumpen Schweiz (FWS)	FWS Zertifikat		EN 16147
	United Kingdom				EN 16147
	China	CNIS			
	Australia	DCCEE			
Mandatory Energy Labelling	United States	FTC	Energy Guide Label		CFR 430
	Canada	Natural Resources Canada	Energy Guide Label		CAN/CSA-C745-03 (R2014)
	Japan	NA	NA	NA	NA
	South Korea				KS B 6410
	EU (27 countries)	EU Commission	EuP program		EN 16147
	Switzerland				EN 16147
	United Kingdom				EN 16147
	China	CNIS	Energy Label		GB/T 23137 - 2008
	Australia	DCCEE	Energy Rating Label		AS/NZS 5125.1:2014
Voluntary Energy Saving Label	United States	EPA & DOE	Energy Star		
	EU (27 countries)	EU Commission			
Mandatory Stand By Warning Label	Australia	DCEE			
	South Korea				

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### Korea

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## China

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- GB/T 21362–2008, *Heat Pump Water Heater for Commercial & Industrial and Similar Uses*

## Addendum 1: Draw Off patterns

### US Draw off patterns to determine EF and FHR

*Selection of Draw Pattern.* HPWHs are tested under a draw profile that depends upon their first-hour rating or their maximum GPM rating whichever is applicable. For water heaters that have been tested according to the first-hour rating procedure, one of four different patterns shall be applied based on the measured first-hour rating, as shown in Table 1 of this section. For water heater that have been tested according to the maximum GPM rating procedure, one of four different patterns shall be applied based on the maximum GPM, as shown in Table 2 of this section.

**TABLE 1—DRAW PATTERN TO BE USED BASED ON FIRST-HOUR RATING**

First-hour rating greater than or equal to:	... and first-hour rating less than:	Draw pattern to be used in simulated-use test
0 gallons	18 gallons	Very-Small-Usage (Table III.1).
18 gallons	51 gallons	Low-Usage (Table III.2).
51 gallons	75 gallons	Medium-Usage (Table III.3).
75 gallons	No upper limit	High-Usage (Table III.4).

**TABLE 2—DRAW PATTERN TO BE USED BASED ON MAXIMUM GPM RATING**

Maximum GPM rating greater than or equal to:	and maximum GPM rating less than:	Draw pattern to be used in simulated-use test
0 gallons/minute	1.7 gallons/minute	Very-Small-Usage (Table III.1).
1.7 gallons/minute	2.8 gallons/minute	Low-Usage (Table III.2).
2.8 gallons/minute	4 gallons/minute	Medium-Usage (Table III.3).
4 gallons/minute	No upper limit	High-Usage (Table III.4).

The draw patterns to be imposed during 24-hour simulated-use tests are provided in Tables 3.1 through 3.4 following. Each draw pattern specifies the elapsed time in hours and minutes during the 24-hour test when a draw is to commence, the total volume of water in gallons (liters) that is to be removed during each draw, and the flow rate at which each draw is to be taken, in gallons (liters) per minute.

**TABLE 3.1—VERY-SMALL-USAGE DRAW PATTERN**

Draw No.	Time during test [hh:mm]	Volume [gallons (L)]	Flow Rate** [GPM (L/min)]
1*	0:00	2.0 (7.6)	1 (3.8)
2*	1:00	1.0 (3.8)	1 (3.8)
3*	1:05	0.5 (1.9)	1 (3.8)
4*	1:10	0.5 (1.9)	1 (3.8)
5*	1:15	0.5 (1.9)	1 (3.8)
6	8:00	1.0 (3.8)	1 (3.8)
7	8:15	2.0 (7.6)	1 (3.8)
8	9:00	1.5 (5.7)	1 (3.8)
9	9:15	1.0 (3.8)	1 (3.8)
Total Volume Drawn Per Day: 10 gallons (38 L)			

\*Denotes draws in first draw cluster.

\*\*Should the water heater have a maximum GPM rating less than 1 GPM (3.8 L/min), then all draws shall be implemented at a flow rate equal to the rated maximum GPM.

**TABLE 3.2—LOW-USAGE DRAW PATTERN**

Draw No.	Time during test [hh:mm]	Volume [gallons (L)]	Flow Rate** [GPM (L/min)]
1*	0:00	15.0 (56.8)	1.7 (6.4)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	1:00	1.0 (3.8)	1 (3.8)
4	10:30	6.0 (22.7)	1.7 (6.4)
5	11:30	4.0 (15.1)	1.7 (6.4)
6	12:00	1.0 (3.8)	1 (3.8)
7	12:45	1.0 (3.8)	1 (3.8)
8	12:50	1.0 (3.8)	1 (3.8)
9	16:15	2.0 (7.6)	1 (3.8)
10	16:45	2.0 (7.6)	1.7 (6.4)
11	17:00	3.0 (11.4)	1.7 (6.4)
Total Volume Drawn Per Day: 38 gallons (144 L)			

\* Denotes draws in first draw cluster.

**TABLE 3.3—MEDIUM-USAGE DRAW PATTERN**

Draw No.	Time during test [hh:mm]	Volume [gallons (L)]	Flow Rate** [GPM (L/min)]
1*	0:00	15.0 (56.8)	1.7 (6.4)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	1:40	9.0 (34.1)	1.7 (6.4)
4	10:30	9.0 (34.1)	1.7 (6.4)
5	11:30	5.0 (18.9)	1.7 (6.4)
6	12:00	1.0 (3.8)	1 (3.8)
7	12:45	1.0 (3.8)	1 (3.8)
8	12:50	1.0 (3.8)	1 (3.8)
9	16:00	1.0 (3.8)	1 (3.8)
10	16:15	2.0 (7.6)	1 (3.8)
11	16:45	2.0 (7.6)	1.7 (6.4)
12	17:00	7.0 (26.5)	1.7 (6.4)
Total Volume Drawn Per Day: 55 gallons (208 L)			

\*

Denotes draws in first draw cluster.

**TABLE 3.4—HIGH-USAGE DRAW PATTERN**

Draw No.	Time during test [hh:mm]	Volume [gallons (L)]	Flow Rate** [GPM (L/min)]
1*	0:00	27.0 (102)	3 (11.4)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	0:40	1.0 (3.8)	1 (3.8)
4*	1:40	9.0 (34.1)	1.7 (6.4)
5	10:30	15.0 (56.8)	3 (11.4)
6	11:30	5.0 (18.9)	1.7 (6.4)
7	12:00	1.0 (3.8)	1 (3.8)
8	12:45	1.0 (3.8)	1 (3.8)
9	12:50	1.0 (3.8)	1 (3.8)
10	16:00	2.0 (7.6)	1 (3.8)
11	16:15	2.0 (7.6)	1 (3.8)
12	16:30	2.0 (7.6)	1.7 (6.4)
13	16:45	2.0 (7.6)	1.7 (6.4)
14	17:00	14.0 (53.0)	3 (11.4)
Total Volume Drawn Per Day: 84 gallons (318 L)			

\*Denotes draws in first draw cluster.

[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 eco-design requirements for water heaters and hot water storage tanks

Heat pump water heaters shall be tested under the conditions set out in Table 4, below. Standard rating conditions for heat pump water heaters, temperatures in dry bulb air temperature (wet bulb air temperature indicated in brackets).

Table 4 – Standard air temperature rating conditions for HPWHs in EU

Heat source	Outdoor air	Indoor air	Exhaust air	Brine	Water
Temperature	+ 7 °C (+6 °C)	+ 20 °C (maximum + 15 °C)	+ 20 °C (+ 12 °C)	0 °C (inlet)/ – 3 °C (outlet)	+ 10 °C (inlet)/ + 7 °C (outlet)

Heat pump water heaters which use ventilation exhaust air as the heat source shall be tested under the conditions set out in Table 5. Maximum ventilation exhaust air available [m<sup>3</sup>/h], at a temperature of 20 °C and with humidity of 5,5 g/m<sup>3</sup>

Table 5 – ventilation exhaust air conditions for testing HPWHs using exhaust air as heat source

Declared load profile	XXS	XS	S	M	L	XL	XXL	3XL	4XL
Maximum ventilation exhaust air available	109	128	128	159	190	870	1 021	2 943	8 830

Benchmarks for Sound Power Level (LWA) outdoors of Heat Pump Water Heaters with:

1. rated heat output ≤ 6 kW: 39 dB;
2. rated heat output > 6 kW and ≤ 12 kW: 40 dB;
3. rated heat output > 12 kW and ≤ 30 kW: 41 dB;
4. rated heat output > 30 kW and ≤ 70 kW: 67 dB.

Benchmark for standing Loss of Hot Water Storage Tanks with Storage Volume (V), expressed in Litres

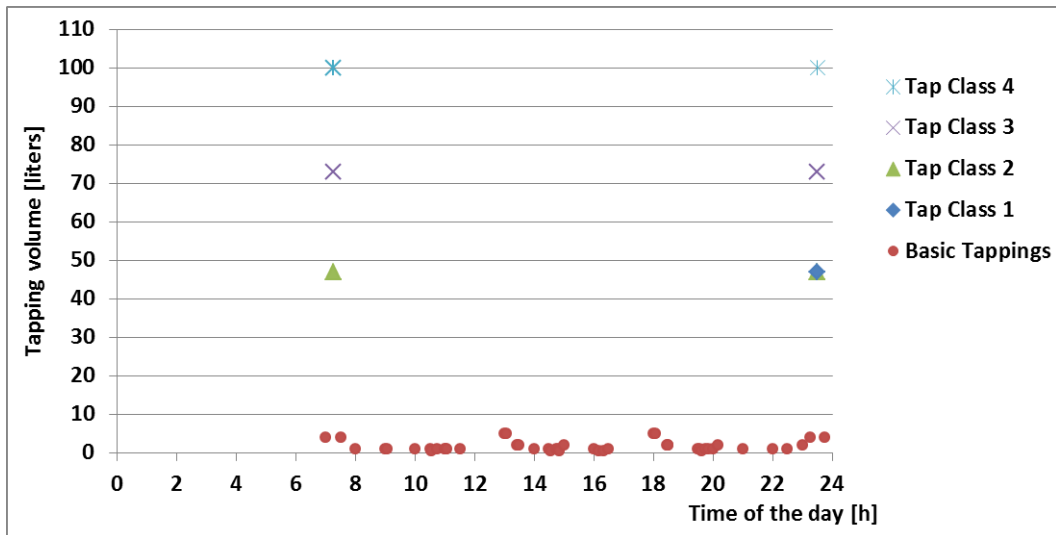
$$5 + 4,16 V^{0,4} \text{ Watts}$$

In this Addendum typical demand patterns are given for each country.

## Netherlands

The Dutch standard patterns for testing DHW-Heat Pumps are shown in the graph below. The pattern consist of a basic demand for (kitchen) sinks and 4 classes of additional demands for the use of bath and showers. The main characteristics of the DHW-demand classes are shown in the table below.

	Basic	Class 1	Class 2	Class 3	Class 4
Net heating demand in [kWh/yr]	1300	1900	2500	3170	3860
in [GJ/yr]	4,7	6,85	9,0	11,4	13,9
Max capacity [ltr/min of 60 °C]	2,5	3,5	3,5	5,5	7,5
Tapping volume					
40 °C [ltr/day]	39	86	133	185	240
55 °C [ltr/day]	42	42	42	42	42
Total equivalent of 60 °C [ltr/day]	61	89	117	149	181



Tapping patterns for the Dutch standard testing procedure of DHW-Heat Pumps

## Switzerland

For designing domestic hot water systems, the building industry is following the standards SIA 385/1[28] and SIA 385/2 [29]from the Swiss Society of Engineers and Architects (SIA). Major topics are legionella prevention, reduced heat losses of tubes and storage tank, hot water demand, tapping time, and heat tracing.SIA 385/1 defines the basic requirements for domestic hot water systems. SIA 385/2 describes the calculation methods for the planning of domestic hot water systems. Requirements for legionella prevention, heat losses (of tubes and storage tank), domestic hot water demand, tapping time, and heat tracing, etc. are defined.

Table 1 defines the hot water demand requirements in different types of buildings (e.g. single and multiple family houses, simple, normal and high standard)and the recommended tapping profiles for dimensioning of domestic hot water systems [29].

Table 1: Hot water demand requirements according to SIA 385/2 [2].

Building type	Note	Domestic hot water consumption in standard liter per day	
		average demand per person	maximum demand per person
Single family house, condominium	simple standard	<b>40*</b>	50
	normal standard	45	60
	high standard	55	70
Multiple family building	simple standard	<b>35*</b>	45
	high standard	45	60

\* these values are used for rough dimensioning

Vetsch et al. (2012) [01] performed field measurements of the domestic hot water consumption in three different objects of multiple family houses. Table 2summarizes the measured results. The average hot water consumptions per person varied from 36 to 44 litres per day. The fluctuation range of the consumption measurements was  $\pm 10\%$  and around 1 to 2 K for the temperature measurement. In all objects, storage tank outlet temperatures above 55°C were observed. The installed storage tank volume matched quite well with the maximum consumption within 24 hours.

Table 2: Summary of field measurements in 3 multiple family house objects, described by Vetsch et al. (2012) [01].

	Object 1	Object 2	Object 3
Buildings	2	1	3
Apartments	48	66	73
Residents	97	128	-
<b>Average hot water consumption [litres/day]</b>			
- object	4285 ± 383	4578 ± 844	6149 ± 756
- per apartment	89.3 ± 8.0	69.4 ± 6.6	84.2 ± 10.4
- per person	<b>44.2 ± 3.9</b>	<b>35.8 ± 3.4</b>	-
Maximum in 1 hour (litres)	814	868	1'249
Maximum in 24 hours (litres)	5'718	6'237	9'257
Installed storage tank (litres)	6'000	8'000	10'000
Supply temperature (storage tank outlet) [°C]	59.6 ± 1.1	55.6 ± 2.2	57.3 ± 1.9

Taking a closer look at object 1, the consumption profiles look quite regular on a weekly, daily, and hourly base. Saturdays and Sundays slightly differ from weekdays (see Figure 1).

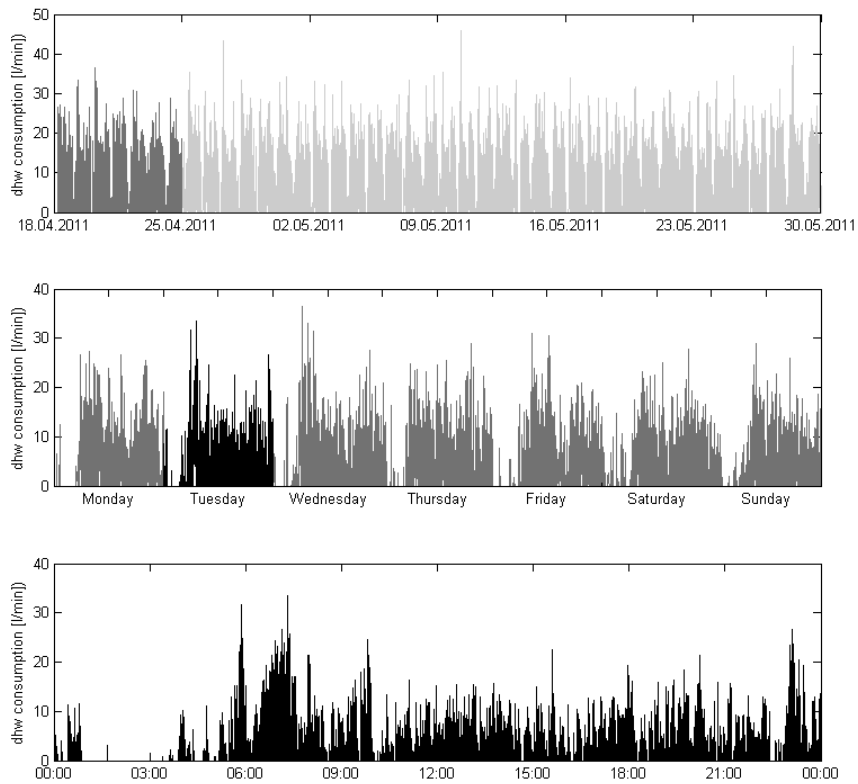


Figure 1: Consumption profiles of object 1 (Vetsch et al. 2012) [01].

Figure 2 compares a typical water consumption profile according to the design Standard SIA 385/2 [29] with the measured consumption of the object 1 described by Vetsch et al. (2012) [01]. The SIA 385/2 postulates a continuous consumption over nearly the whole day, which has been confirmed by the experimental measurements.

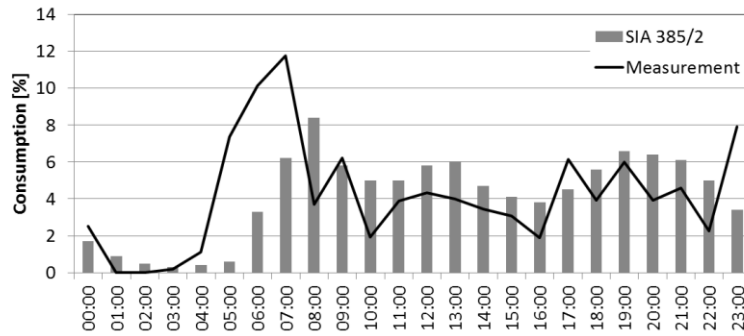


Figure 2: Comparison of the hot water consumption profile (Monday to Thursday) according to standard SIA 385/2 [2] with measurement of object 1Vetsch et al. (2012) [01].

Table 3 summarizes some recent studies of Bürgi et al. (2013) [30] and Heim et al. (2016) [31] with measurements on the domestic hot water consumption to verify the correct dimensioning and installation of a building complex with MINERGIE-P-Standard. In contrast to Bürgi et al. (2013) [30] and Vetsch et al. (2012) [01], Heim et al. (2016) [31] monitored the domestic hot water consumption of single family houses and apartments (in total 10 households) over one year, which enables to derive the individual consumption behaviour.

Table 3: Measurement results of domestic hot water consumptions from Bürgi et al. (2013) and Heim et al. (2016).

	Bürgi et al. (2013) [4]	Heim et al. (2016) [5]										
	2 buildings and 40 apartments	10 households studied, number of residents living in the household										
												Mean values
No. of residents	80	2	5	4	2	2	4	1	3	2	2	2.7
Installed storage tank [L]	5000	300	210	300	300	300	300	110	280	250	300	265
Supply temperature [°C] (storage tank outlet)	-	69.5	65.4	64.6	63.8	54.3	66	56	60.8	71.3	67.2	63.9
Water Consumption [L/]												
- object	3'320	-	-	-	-	-	-	-	-	-	-	-
- per apartment	83	-	-	-	-	-	-	-	-	-	-	-
- per person	41.5	49	21	39	45	8	18	21	22	65	48	33.6

The measured mean value of 33.6 liters per day and person was close to the 35 liters per day and person for households in multiple family houses described in the guideline Standard SIA 385/2:2015 (for comparison in single family houses 40 liters per day and person are used for design). The individual values of the 10 households studied, fluctuated by a factor of 8 between 8 and 65 litres per day person [5]. It is worth mentioning that in that study the domestic hot water was supplied by electrical water heaters providing relatively high supply temperatures of 63.9°C on average. Interestingly, there was no correlation between the specific hot water consumption and the number of residents in the households. It is expected that the specific consumption depended much more on the individual activities of the residents, such as the intensity of the personal care or the personal commitment to a more economical water consumption.

Heim et al. (2016) [31] also identified so-called “predominantly morning consumers” and “predominantly evening consumers” when comparing individual tapping profiles (see Figure 3). This is for example in agreement to the findings of Edwards et al. (2015) [32], who observed similar water consumption patterns between houses in Canada.

morning consumers

evening consumers

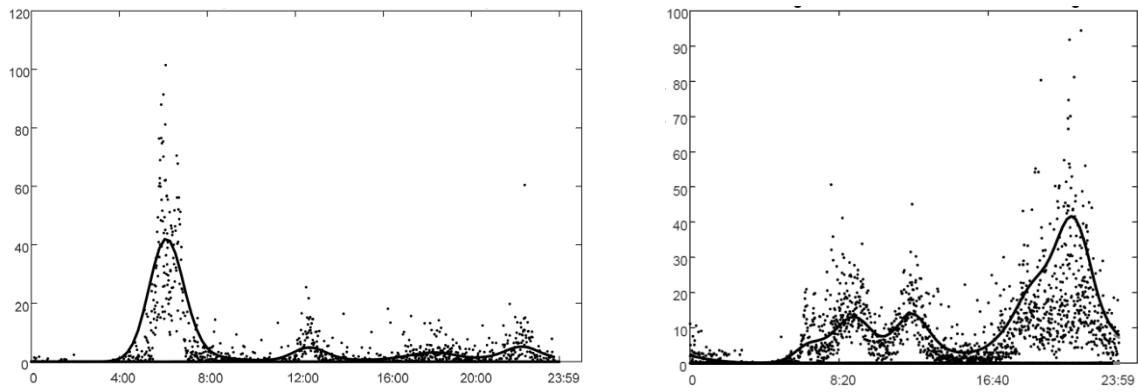


Figure 3: Characteristic hot water consumption profiles (tap profiles) for the predominantly morning and evening consumer (from the measurements of Heim et al. (2016) [31]).

Like in other countries, the hot water consumption profiles (tapping curves) in Swiss multiple family houses are rather continuous due to the averaging effect of the individual human behaviour. In single households a great variety in water usage is found depending upon human behaviour factors (e.g. shower/bathing, personal care, etc.) demanding higher flexibility of the heat pump water heater system and may lead to oversizing of the system.

## United Kingdom

### 4.3 Field trials

Table 4 of the report on the EST hot water field trials<sup>12</sup> showed that combi boilers used more hot water on average than regular boilers. Further analysis of the source data is shown in table 7 below. The analysis in table 7 is restricted to dwellings with combi or regular boilers and at least 8 out of 12 monthly records from July 2007 to June 2008.

**Table 7: Measured hot water usage in field trials**

	Regular	Combi	Difference
Sample number	56	31	
Average number of occupants	3.1	3.0	
Daily volume (litres/day)			
Mean	81.2	105.3	23
Median	105.9	128.9	24
Standard deviation	78.0	77.0	
Standard error	10.4	13.8	17.3
95% confidence interval	± 20.8	± 27.6	± 34.6
90% confidence interval	± 17.0	± 22.6	± 28.3

On average, combi boilers are using 24 litres/day more than regular boilers in dwellings that have a similar number of occupants (the dominant factor influencing hot water usage). Average temperature rises delivered by the combi boilers or hot water cylinders are also similar (37K on average).

As the standard deviations of samples are similar we may conclude that the difference is within two standard errors of the difference between the samples, that is:  $24 \pm 34.6$  litres with 95%

<sup>12</sup> Measurement of Domestic Hot Water Consumption in Dwellings, EST, 2008

Source: RdSAP

## Europe

In the tables below the three most relevant tapping patterns according to the EU-directive “Directive 2010/30/EU - C(2013) 818 final” are shown.

h	S				M				L			
	$Q_{tap}$ kWh	$f$ l/min	$T_m$ °C	$T_p$ °C	$Q_{tap}$ kWh	$f$ l/min	$T_m$ °C	$T_p$ °C	$Q_{tap}$ kWh	$f$ l/min	$T_m$ °C	$T_p$ °C
07:00	0,105	3	25		0,105	3	25		0,105	3	25	
07:05					1,4	6	40		1,4	6	40	
07:15												
07:26												
07:30	0,105	3	25		0,105	3	25		0,105	3	25	
07:45									0,105	3	25	
08:01					0,105	3	25					
08:05									3,605	10	10	40
08:15					0,105	3	25					
08:25									0,105	3	25	
08:30	0,105	3	25		0,105	3	25		0,105	3	25	
08:45					0,105	3	25		0,105	3	25	
09:00					0,105	3	25		0,105	3	25	
09:30	0,105	3	25		0,105	3	25		0,105	3	25	
10:00												
10:30					0,105	3	10	40	0,105	3	10	40
11:00												
11:30	0,105	3	25		0,105	3	25		0,105	3	25	
11:45	0,105	3	25		0,105	3	25		0,105	3	25	
12:00												
12:30												
12:45	0,315	4	10	55	0,315	4	10	55	0,315	4	10	55
14:30					0,105	3	25		0,105	3	25	
15:00												
15:30					0,105	3	25		0,105	3	25	
16:00												
16:30					0,105	3	25		0,105	3	25	
17:00												
18:00	0,105	3	25		0,105	3	25		0,105	3	25	
18:15	0,105	3	40		0,105	3	40		0,105	3	40	
18:30					0,105	3	40		0,105	3	40	
19:00					0,105	3	25		0,105	3	25	
19:30												
20:00												
20:30	0,42	4	10	55	0,735	4	10	55	0,735	4	10	55
20:45												
20:46												
21:00									3,605	10	10	40
21:15					0,105	3	25					
21:30	0,525	5	45		1,4	6	40		0,105	3	25	
21:35												
21:45												

Where: ‘useful water flow rate’ ( $f$ ) means the minimum flow rate, expressed in litres per minute, for which hot water is contributing to the reference energy, as specified in Annex VII, Table 3;

‘useful water temperature’ ( $T_m$ ) means the water temperature, expressed in degrees Celsius, at which hot water starts contributing to the reference energy, as specified in Annex VII, Table 3;

‘useful energy content’ ( $Q_{tap}$ ) means the energy content of hot water, expressed in kWh, provided at a temperature equal to, or above, the useful water temperature, and at water flow rates equal to, or above, the useful water flow rate, as specified in Annex VII, Table 3;

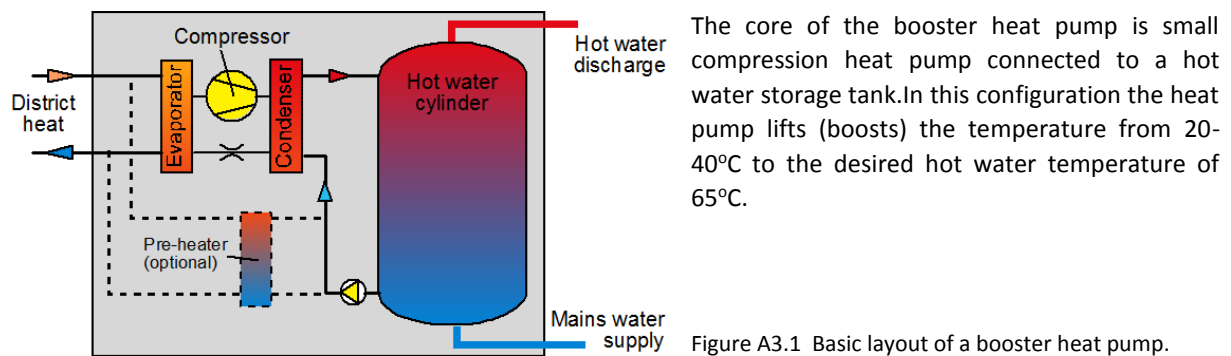
‘energy content of hot water’ means the product of the specific heat capacity of water, the average temperature difference between the hot water output and cold water input, and the total mass of the hot water delivered;

‘peak temperature’ ( $T_p$ ) means the minimum water temperature, expressed in degrees Celsius, to be achieved during water draw-off, as specified in Annex VII, Table 3;

## Addendum 2 – Test procedures for Booster Heat Pumps

Presented at the 12<sup>th</sup> IEA Heat Pump Conference in the paper: [Booster Heat Pump, development of test procedure and calculation methodology in order to estimate the energy performance in various domestic applications](#)

A test procedure for this innovative concept has been developed and already a number of booster heat pumps have been tested getting a [conformity declaration](#).



The test procedure to assess the energy performance of booster heat pumps has been defined in a previous project financed by the ministry of Economic Affairs through RVO [2]. In the test procedure a booster heat pump, integrated with the storage hot water tank is tested with a fixed hot water demand (class 2-4), with supply temperatures in the ranging from 24 to 40°C. The tests give the generation efficiency, including parasitic energy consumption (e.g. to drive circulation pumps) and heat losses.

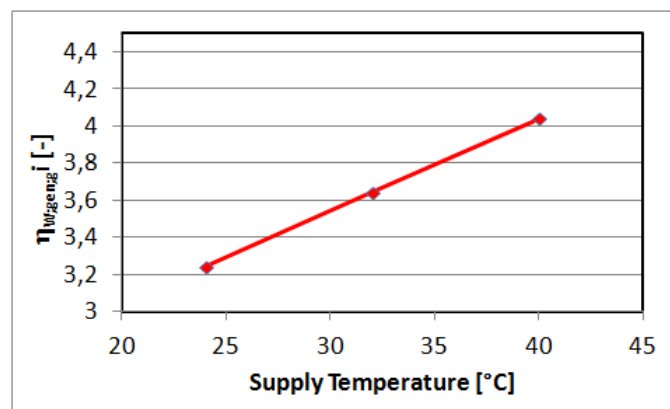


Figure A3.2  $\eta_{w,gen,gi}$  of a booster heat pump, as tested by KIWA for a tap water heat demand of 14 GJ (class 4, according to NEN 7120).

The generation efficiency (COP) can be in the range of 3-4. Given the conversion factor from primary energy (gas) to electricity (primary energy factor) of 1/2,15=46 %, this indicates that the efficiency from primary energy to hot water in principle could be in the range of 140 - 190%.

For traditional heat pumps with an ambient or ground heat source this calculation reflects nearly the full picture. For booster heat pumps however the heat source generally also requires primary energy for its generation, which reduces the overall generation efficiency.

The aspect of the generation efficiency of the district heat system illustrates that the energy performance assessment of the booster heat pump not only relates to the Dutch standard for energy efficiency for buildings EPG (NEN7120), but also to the EMG (NVN7125) incorporating other energy sources like district heating. This in

fact makes the comparison of domestic hot water heat pumps to competing systems less simple. The ministry of Economic Affairs thereafter asked Berkelto develop a calculation model to fit into the Dutch building standard.

The relevant question is how the booster heat pump fits in the Dutch standards for energy performance assessment. The two most relevant standards regarding energy performance in de built environment are NEN7120 (EPG) and NVN7125 (EMG). The EPG I considering the Energy performance of buildings (EnergiePrestatie van Gebouwen), the EMG is about the Energy performance standard for provisions at district level; (EnergieprestatienormvoorMaatregelen op Gebiedsniveau).

Conform the Building Regulation 2012, item 5.2 and NEN7120 14.6.4.5, the two standards must be treated in a staged manner:

1. Starting with a 100 % reference generation efficiency for district heat  $\eta_{H:gen;equiv;dh}$ , EPG should give an Energy Performance Coefficient (EPC) which is maximum 1,33 times the currently admissible value ( $1,33 \times 0,6 = 0,8$ ). If this criterion is met, in a second stage:
2. Calculating the generation efficiency for (district) heat using EMG and substitution in EPG (replacing the reference generation efficiency) should give an EPC which is maximum equal to the currently admissible value (0,6).

Before arriving at detailed treatment of calculations in the EPG, the heat source characteristics must be clear. In parallel mode, the booster heat pump is supplied from the district heating network, with known capacity, known temperature and (from NVN7125) known generation efficiency. For the building as a heat source the capacity and temperature level is not derived as easily. Though in principle it would be possible to calculate the available cooling load in a separate routine (using all relevant building parameters), a better strategy would be to make use of NEN7120 calculations that are done anyway. To that end, NEN7120 evaluates the need for space cooling ( $Q_{C;nd}$ ), according to equation:

$$Q_{C;nd} = a_{C;red} (Q_{C;gn} - \eta_{C;ls} Q_{C;ht}), \text{ with } Q_{C;nd;net} \geq 0 \quad (3.1), (EPG7.2)$$

All equations are evaluated on a monthly basis, with (monthly) values for ambient conditions and indoor setpoint temperatures of 24°C for cooling (EPG, 13.1).

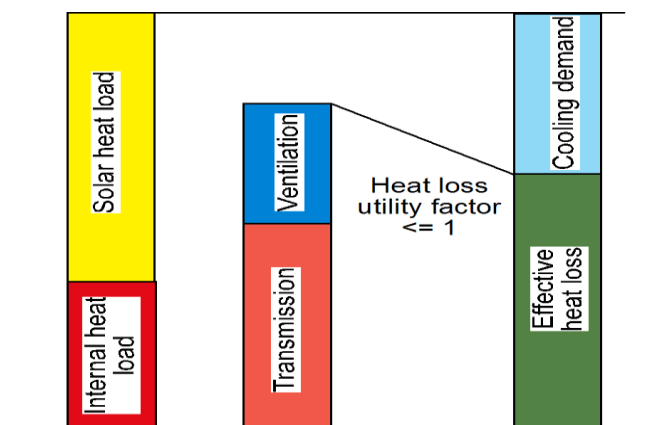
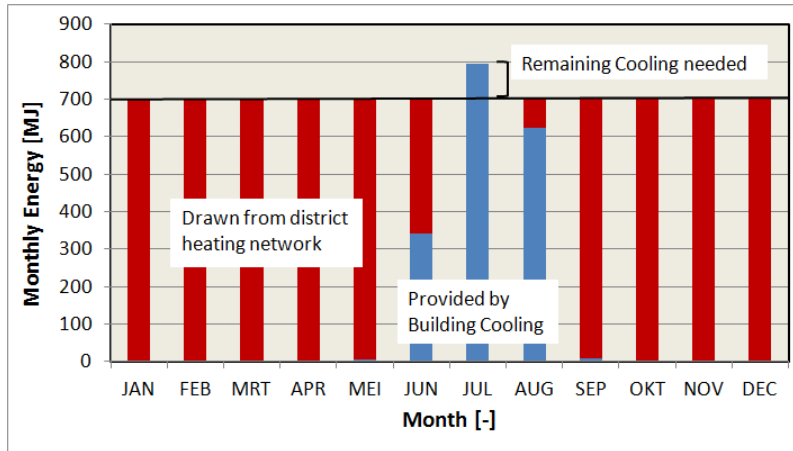


Figure A3.3 Cold demand depending on heat gain and effective heat loss

Note that (cf. EPG8.1) heat transfer between indoor and outdoor are calculated on the basis of the indoor setpoint temperatures, not on actual indoor temperatures (which are not calculated in EPG). Correction for the difference between actual and setpoint temperatures (and dynamic effects) is done with the correction parameters for effective heat loss  $\eta_{C;ls}$ .

It appears that calculation of the building cooling load depends strongly on the specific building characteristics (transmission, ventilation, solar admittance and internal heat load) and a general rule cannot be given.

Figure A3.4 Graphical representation of thermal energy supply to the booster heat pump, either by the district heating



network and/or building summer cooling. For this illustrative example, the booster heat pump thermal energy need is arbitrarily set at 700 MJ/month and cooling need adopted from a reference building calculation.

NEN7120 uses the 24°C setpoint temperature for calculation of cooling loads.

Though, using equations from NEN7120, in principle it would be possible to reconstruct the cooling load for a setpoint temperature lower than 24°C:

- This is not a standard routine.
- It would lose conformity with NEN7210 and would be subject to debate.

For convenience and promptness, for this moment, the cooling load ( $Q_{C,nd}$ , as quantified by NEN7120 with 24°C setpoint temperature) is adopted as the secondary heat source for the booster heat pump. Adopting the setpoint temperature of 24°C facilitates easy determination of the cooling load as it part of the standard calculation routine in NEN7120. It is also standard calculated (and output of the NEN7120 software) and thus can be retrieved easily. If desired, the potential and conformity aspects of a lower setpoint temperature can be evaluated in a parallel project.

Figure A3.4 illustrates the advantages of using building cooling load:

- Reduction of district heat demand.
- Reduction of summer cooling need.

The elaboration in NEN7120 compliant equations is given in the next chapter.

## Addendum 3 - Ecodesign Directive

[Ecodesign Directive](#) for electrical heat pumps

The Ecodesign Directive 2009/125/EC (sometimes called the ErP Directive) requires that energy-related products fulfil ecodesign minimum levels of energy efficiency and environmental performance. The Directive is implemented through Commission Regulations, for various specific products.

For example, Commission Regulation N° 813/2013 refers to space heaters up to a heat output of 400 kW, i.e., devices that provide heat to a building's water-based central heating system, up to a heat output of 400 kW. The regulation also applies to combination heaters, which provide domestic hot water in addition to space heating.

The regulation covers heat pumps, as well as gas and oil boilers, electric boilers, cogeneration (CHP, combined heat and power) boilers. It also applies to "packages" (for example, space heater + supplementary space heater + solar thermal device + temperature control). Its requirements apply since 26 September 2015.

For electrically driven heat pumps (air-to-water, water-to-water and brine-to-water heat pumps), this regulation includes the following requirements:

For both heat pumps providing space heating and combination heat pumps:

- a minimum seasonal space heating energy efficiency, for an "average" European climate;
- a maximum noise level, indoors and/or outdoors.

For combination heat pumps: a minimum water heating energy efficiency according to the declared load profile (i.e., a given sequence of domestic hot water draw-offs).

The specific thresholds, for seasonal space heating energy efficiency and water heating energy efficiency, will become higher from 26 September 2017 onwards.

The required level for the seasonal space heating energy efficiency of low-temperature heat pumps (i.e., designed to deliver their declared capacity at a water temperature of 35°C, and which cannot go up to 52°C when outdoor air temperature is -7°C) is also higher than for other heat pumps.

The regulation also lists which data must be published in the products' technical documentation.

In addition, the regulation defines the way to assess the energy efficiency for of space heating and water heating. For example, the seasonal space heating energy efficiency of heat pumps, declared in terms of primary energy, is derived from the seasonal coefficient of performance based on part-load performance data, and corrected by contributions accounting for temperature controls and, if applicable, for the electricity consumption of ground water pump(s).

Transitional measurement and calculation procedures are listed in a Commission Communication (referenced 2014/C 207/02), until harmonised European standards are published that define how to measure and test the relevant parameters for the performance assessment. These standards are developed as required by a Commission Implementing Decision on a standardisation request (Mandate M535), approved by the European Committee for Standardisation (CEN). A standard for the energy performance of electrical heat pumps was published in March 2016 (EN 14825:2016) and should be listed in the Official Journal of EU as a harmonised standard.

The Ecodesign Directive requires that manufacturers keep and make available EC declarations of conformity, and affix CE markings. For electrical heat pumps, the implementing Regulation N° 813/2013 defines rules for the

conformity assessment: this can depend on manufacturer decisions concerning internal design control or management systems – as described in the annexes to the Ecodesign Directive. Regulation N° 813/2013 also describes the verification procedure for market surveillance by Member States.

Guidelines have been published by the European Commission, including related Frequently Asked Questions.

The Energy Labelling Directive for electrical heat pumps

The Energy Labelling Directive 2010/30/EC imposes mandatory labelling and information requirements that indicate the consumption of energy and other resources by energy-related products.

A Commission Delegated Regulation supplementing Directive 2010/30/EC has been published for space heaters and combination heaters up to 70 kW (Commission Regulation N° 811/2013). The Regulation defines energy efficiency classes, the contents of the label and the product information that should be made available to consumers.

Note that space heaters between 70 and 400 kW must fulfil Ecodesign requirements even though they are not covered by the energy labelling regulation.

For electrical heat pumps, the label must include the following information:

- the supplier's name or trademark;
- the appliance name (supplier's model identifier);
- the rated output under three European climates (average, colder and warmer), for medium- and/or low-temperature applications (55 °C and 35 °C respectively);
- the seasonal space heating energy efficiency class for medium- and/or low-temperature applications (from A++ to G until September 2019 and from A+++ to D after this date);
- a European map displaying the three indicative temperature zones;
- for combination heat pumps, the water heating energy efficiency class for the declared load profile (from A to G until September 2019 and from A+ to F after this date);
- the sound power level indoors and/or outdoors;
- for combination heat pumps able to work only during off-peak hours, a pictogram showing this.

For medium temperature heat pumps, the regulation requires provision of a label with energy efficiency classes for both low- and medium-temperature applications. For combination heat pumps, only the medium temperature energy class is mentioned, along with the energy class for water heating energy efficiency (See Image 1, Image 2 at the slideshow above).

If a heat pump is made available on the market or put into service with additional devices (temperature controls, supplementary boiler, solar device), a supplementary label shall indicate the energy efficiency of the package.

The Energy Labelling Directive requires that suppliers produce technical documentation which is sufficient to assess the accuracy of the information contained in the label. The supplementing Regulation N° 811/2013 describes the verification procedures for market surveillance purposes.

In May 2013, the European Commission launched the review process of the Energy Labelling Directive. The report of this review and its accompanying document were published in July 2015.

Impact of these two Directives on heat pumps

The Ecodesign and Energy Labelling Directives have significant implications for heat pumps:

- they rely on new methods to assess product energy efficiency, based on seasonal energy performance rather than on standard rating conditions;
- they have created a need for revision of the corresponding European standards;
- they define requirements that phase less energy-efficient products out of the market, with more ambitious thresholds entering into force from September 2017;
- they govern the labelling of products for better information of consumers.

The European Commission published Guidelines that summarise the most relevant information which would help stakeholders (including industry and public authorities) to implement these regulations. A Consumer's Guide presenting the label is also available in several languages.

Several stakeholders have also published documents providing guidance, e.g., the Danish Energy Agency and the Federal Association of German Heating Industry (Bundesverband der Deutschen Heizungsindustrie - BDH).



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