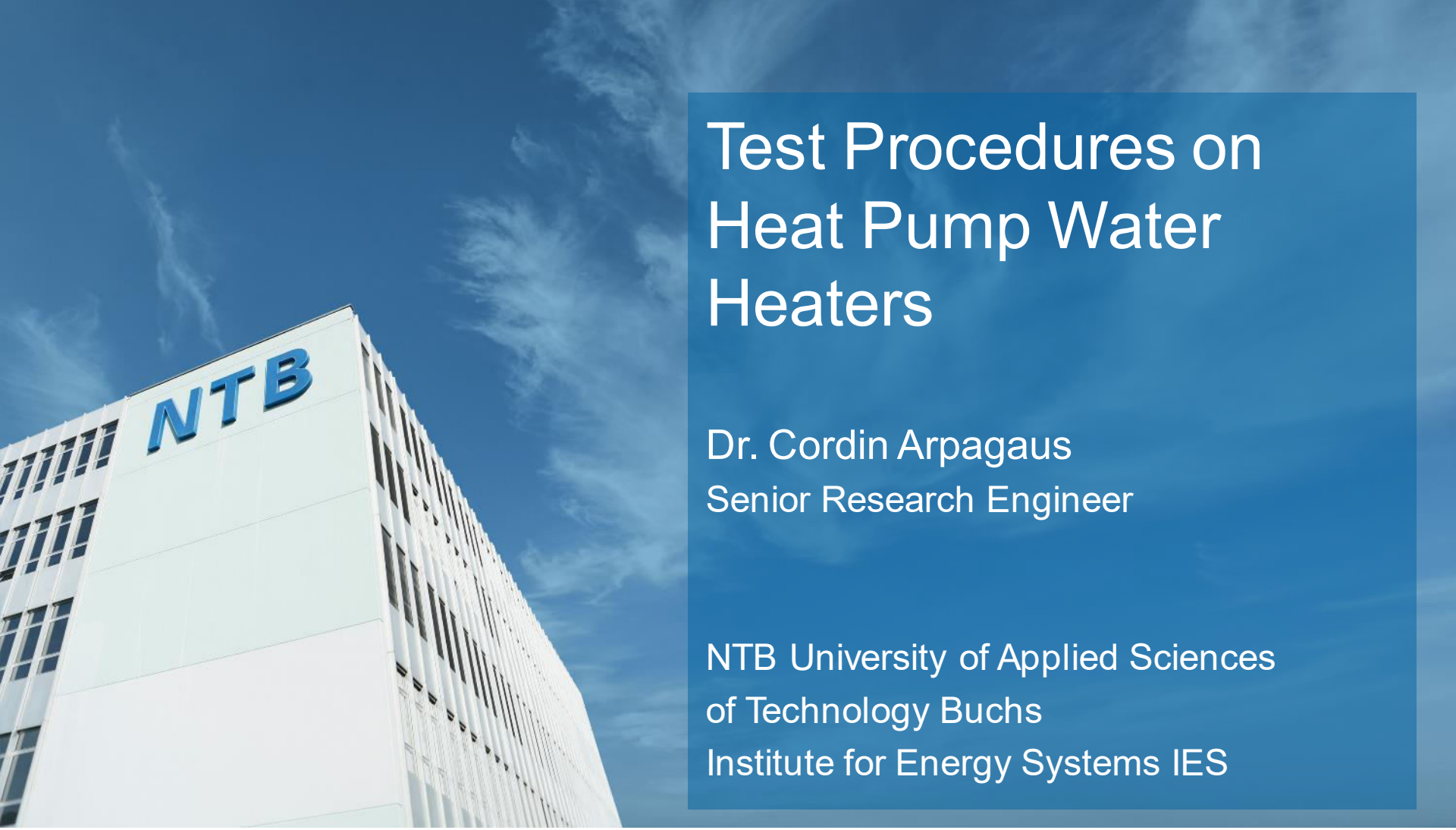

Test Procedures on Heat Pump Water Heaters

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University of Applied Sciences of Eastern Switzerland

IEA HPT Annex 46, 7th Working Meeting
May 16-17, 2019, Seoul, South Korea

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Contents

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- Standard EN 16147
- Overview of test methods - focus on Europe, Japan, USA
- Discussion towards global harmonization

Heat Pump Test Center (WPZ) in Buchs, Switzerland

Certified according to EN 17025

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WPZ
Wärmepumpen-Testzentrum

Air/Water Heat Pumps:

- 2 x 50 kW and 2 x 25 kW at A2/W35 (EN 14511)

- founded 1993
- Temperature: -25°C to +45°C (air)
- Acoustic measurements are possible (EN 12102 and ISO EN 9614)

SWISS ACCREDITATION sas.admin.ch STS 0499

ilac-MRA

European Quality Label for Heat Pumps ehpa

Warmwasser-Wärmepumpe GEPRÜFTE QUALITÄT

www.wpz.ch, E-Mail: wpz@ntb.ch

Brine/Water Heat Pumps:

- 2 x 100 kW at B0/W35 (EN 14511)

Domestic Hot Water Test Benches

- Tap profiles S to XXL (**EN 16147** and ErP-Standards)

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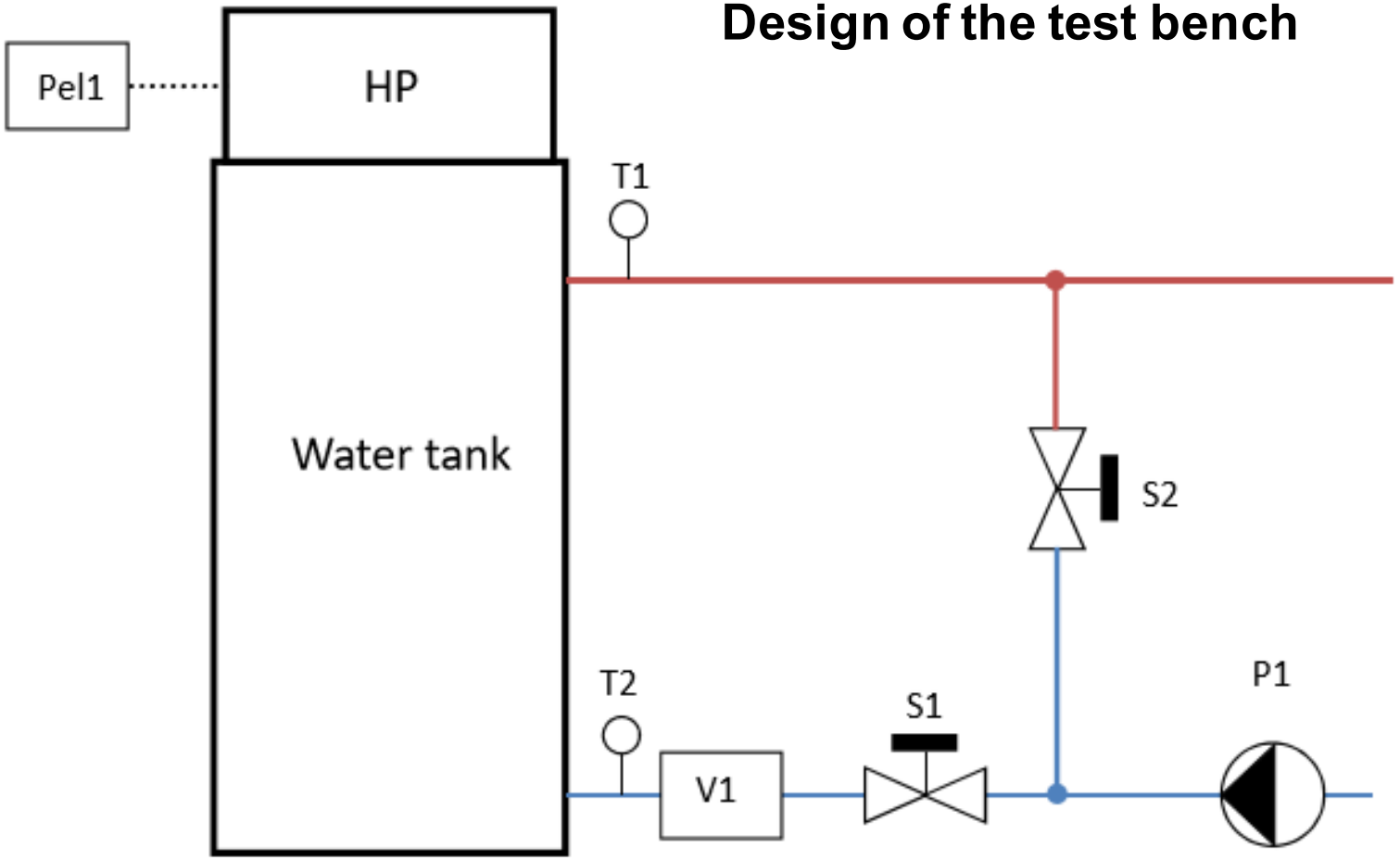
The heat pump test center WPZ follows the testing standard EN 16147 for DHW heat pumps

Design of the test bench



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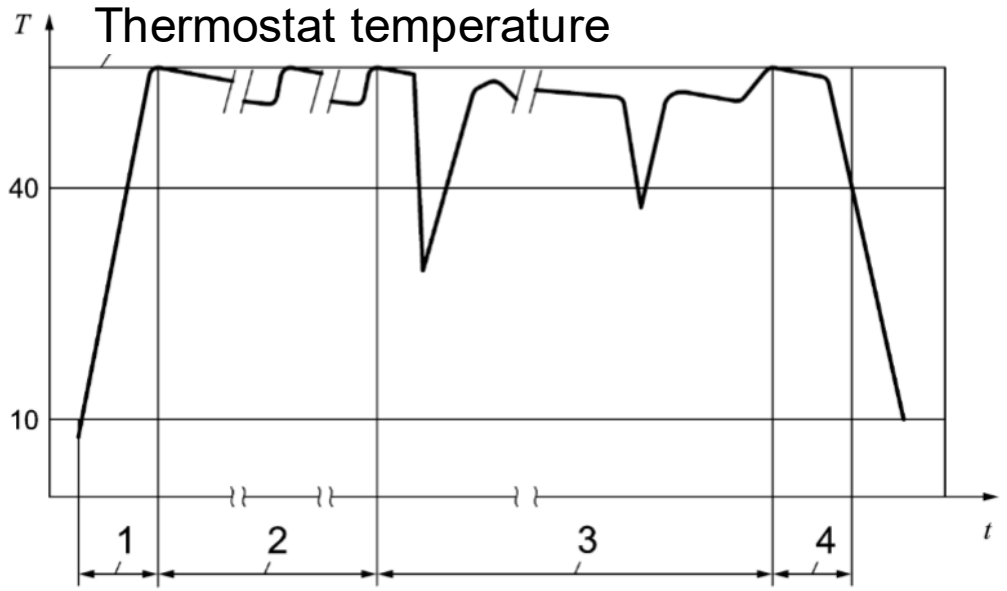
The heat pump test center WPZ follows the testing standard EN 16147 for DHW heat pumps

Test Procedure



1: **Heating up period** from 10 °C until first time compressor switch-off by the thermostat (around 55 °C)

2: **Standby period** (min. 48 h) to determine standby power input by measuring the electrical power input over an integral number of on-off cycles of the compressor.

3: **COP determination** at defined draw-offs (min. 24 h) (e.g. hand washing, bathing, dish washing, etc.)

Profile	S	M	L	XL	XXL
Individual draw-off per day [kWh]	2.10	5.85	11.66	19.07	24.53

4: **Determination of the reference hot water temperature.** This test is started when the compressor switches off at the end of the last measurement period for the load profile. A continuous hot water draw-off is started and continues until the hot water temperature falls below 40 °C.

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The heat pump test center WPZ follows the testing standard EN 16147 for DHW heat pumps

Measurements at 2°C (colder), 7°C (average), 14°C (warmer), and 20°C (indoor air)

Minimal COP requirements for DHW heat pumps at different tap profiles

Storage volume in liter	Tap profiles	Minimal COP at air source conditions	
		A20	A7
< 150	M	3.20	2.30
150 to 249	L	3.20	2.30
250 to 349	XL	3.20	2.30
350 and higher	XXL	3.20	2.30

A20/W10-55 A7/W10-55

Mandatory in Europe since 2015

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Supplier and model

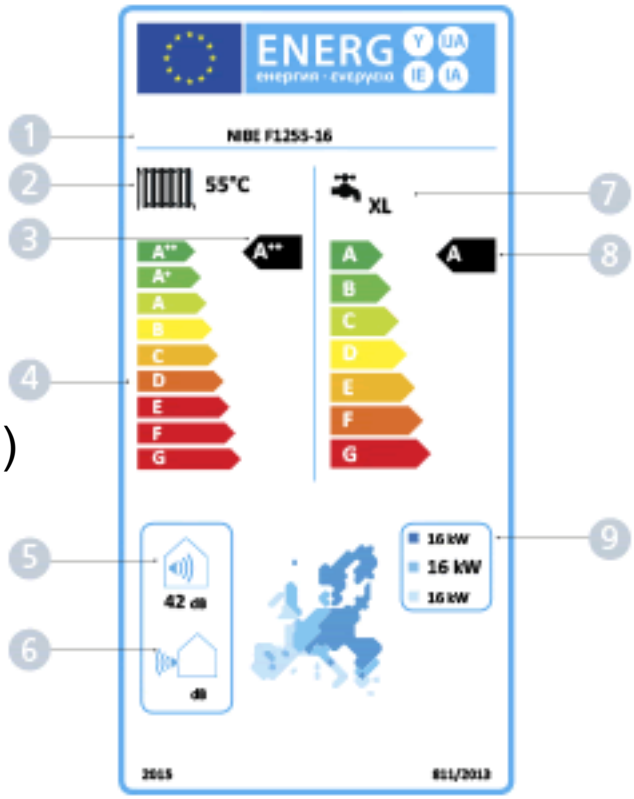
Heating

Energy class heating

Scale of efficiency classes (up to A++ for space heating)

Sound power level indoors

Sound power level outdoors



Hot water profile used

Energy class hot water (up to A)

Rated heat output at different climate zones

Swiss quality label:

WPSYSTEMMODUL
EFFIZIENTE WÄRMEPUMPEN MIT SYSTEM

It guarantees homeowners optimum planning and construction of heat pump systems up to approx. 15 kW heating capacity for new buildings and renovations (incl. installation and maintenance).

Climatic regions in Europe (warm, normal, cold)

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3 different climatic zones (warm, normal, and cold)

Examples:

- Switzerland «cold»
- The Netherlands «normal»
- south of England «warm»

The default flow heat supply temperatures are 55 °C and / or 35 °C degrees.

Source temperatures (EU-regulation No 812/2013)

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)

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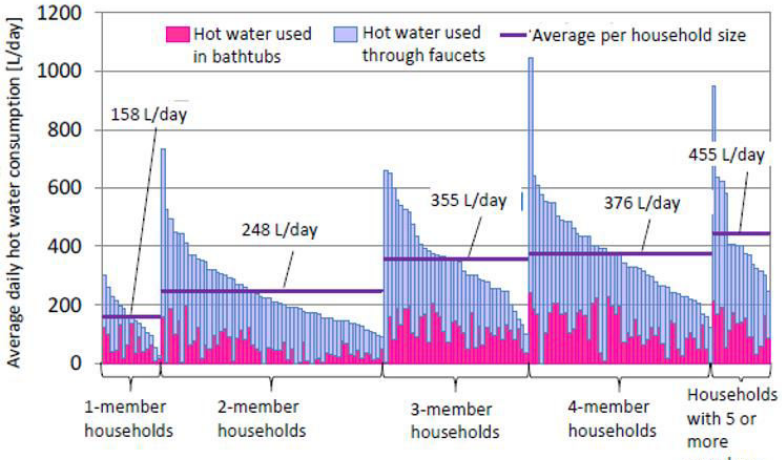
Major differences between test methods in use in different regions of the world

Japan

- **Bath culture**
- **System with and without tank**
- **Ambient and water test conditions (JIS C 9220)**
- **Draw-off cycles of 24 hour (4 types)**

Standard house (456 L at 40°C)
Small house (278 L at 40°C)

Hot water use per household in Japan



Season	Ambient air °C[8]	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

DB: Dry Bulb; WB: Wet Bulb Temperature

Hot water delivery at 40 °C:
wash basin (5 L/min, < 5L)
kitchen (5 L/min, <25 L)
bath (10 to 15 L/min, 180 L)
shower (10 L/min, 20, 50 L)

51 or 31 draws

Climatic regions in Japan and humidity factors

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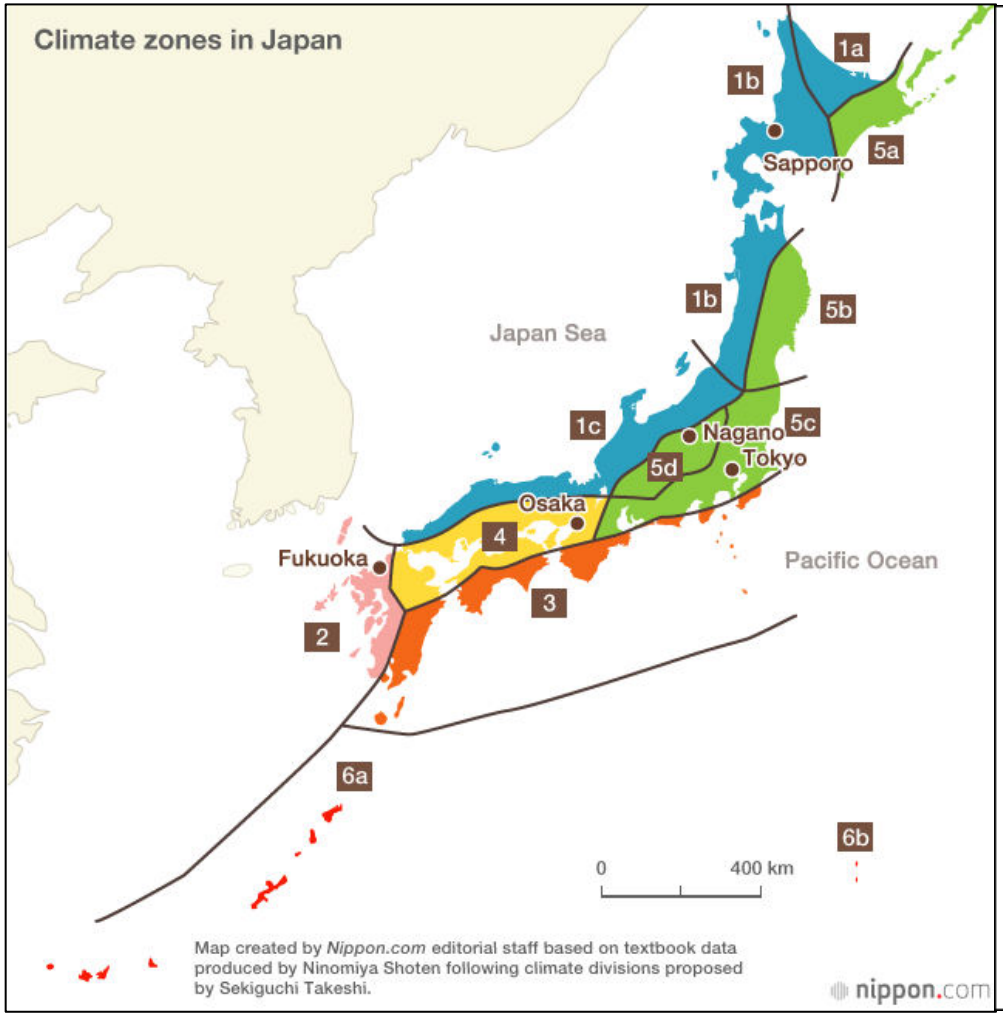

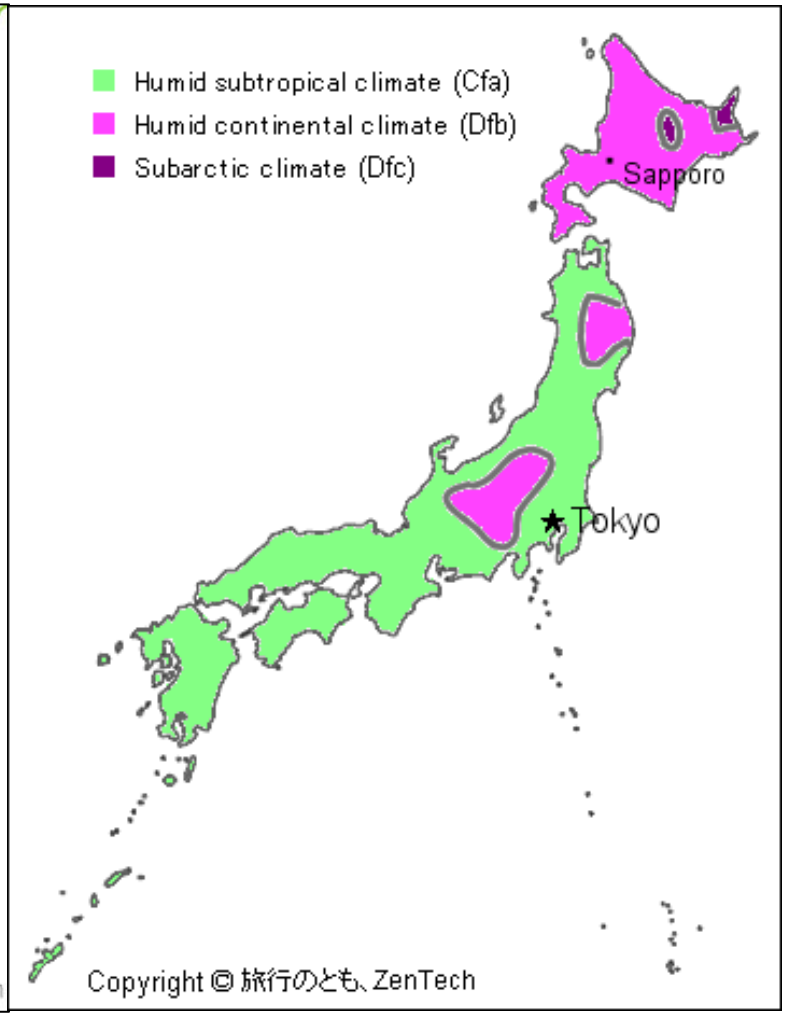

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Major differences between test methods in use in different regions of the world

US

American Energy Manufacturing and Technology Connection Act (AEMTCA)

Test procedures account for **tank heat loss effects** over a 24-h test and to normalize test results to standard ambient air and tank water temperature conditions

Set points:
water temperature 51.7°C
inlet water 14.4°C
ambient air 19.7°C (35 to 45% r.h.)

4 draw-off patterns from very small to high

First Hour Rating (FHR) is a measure of the available hot water capacity of the water heater (water drawn from the tank during 1 hour)

Unified Energy Factor (UEF) is a measure of the efficiency of the system (DOE 2013)

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

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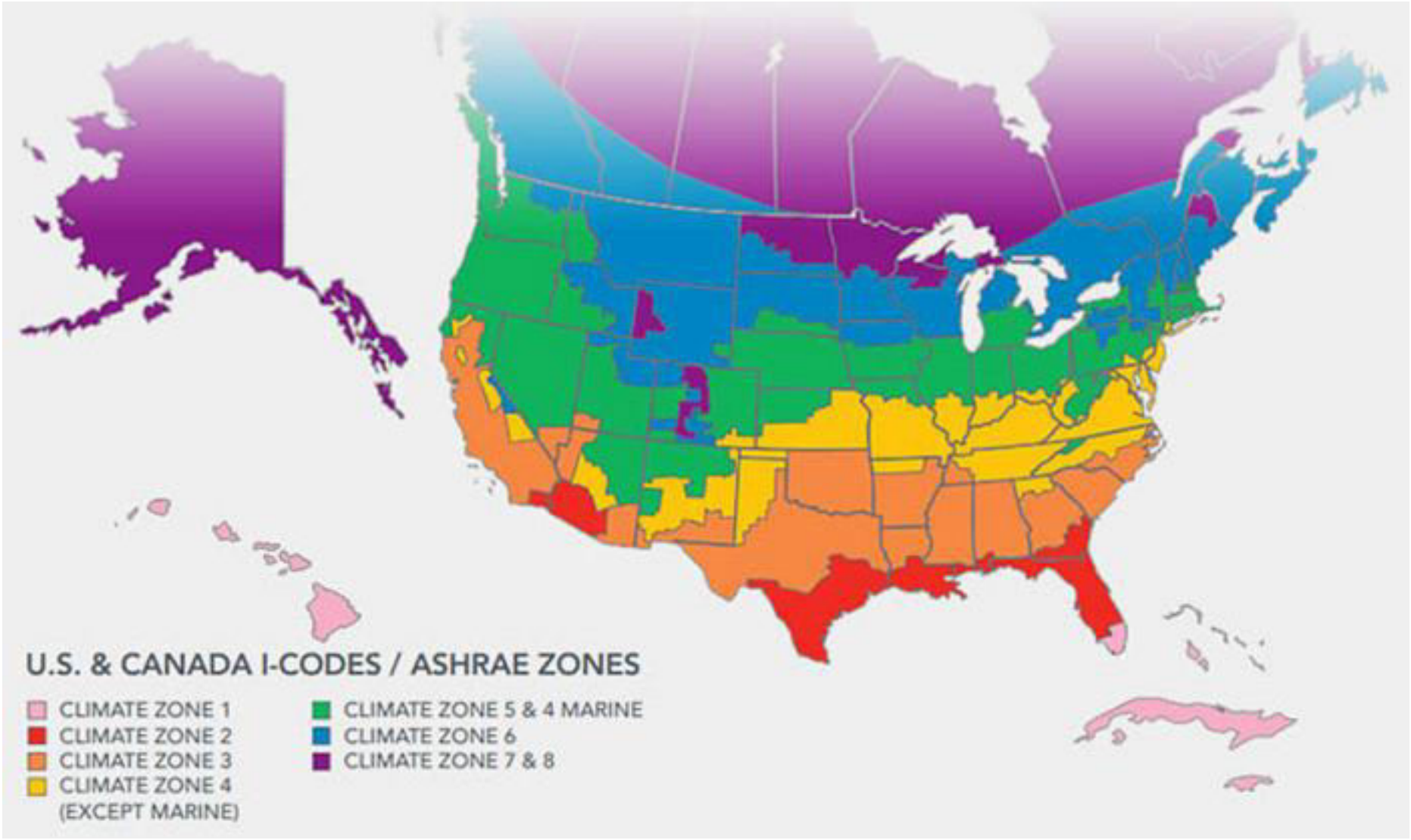

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Major differences between test methods in use in different regions of the world

Korea

export driven economic structure

Korea Industry Standard KS (KS B 6410)
air heat source, heat pump boiler, < 23 kW, max. pressure when using storage tank 0.34 MPa

Application: Heating only, hot water supply only or heating/hot water supply

SCOP weighted values

SCOP_C
SCOP_M
SCOP_W

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%	28%	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

Quote

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

A great number of test methods for HPWH are in use in different regions of the world

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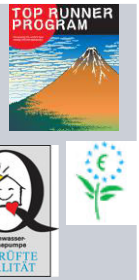
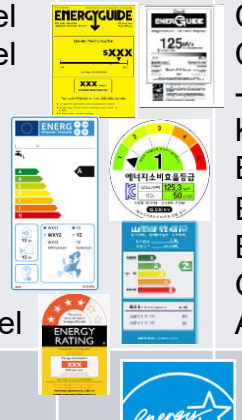
Characteristics	Country	Organisation	Label/program		Test standards
Voluntary Minimum Energy Performance Standard	US Canada Japan Sourth Korea EU (27) Switzerland UK China Australia	DOE Natural Resources Canada METI - EU Commission FWS - CNIS DCCEE	- - Top Runner Program - Eco design FWS Zertifiikat -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

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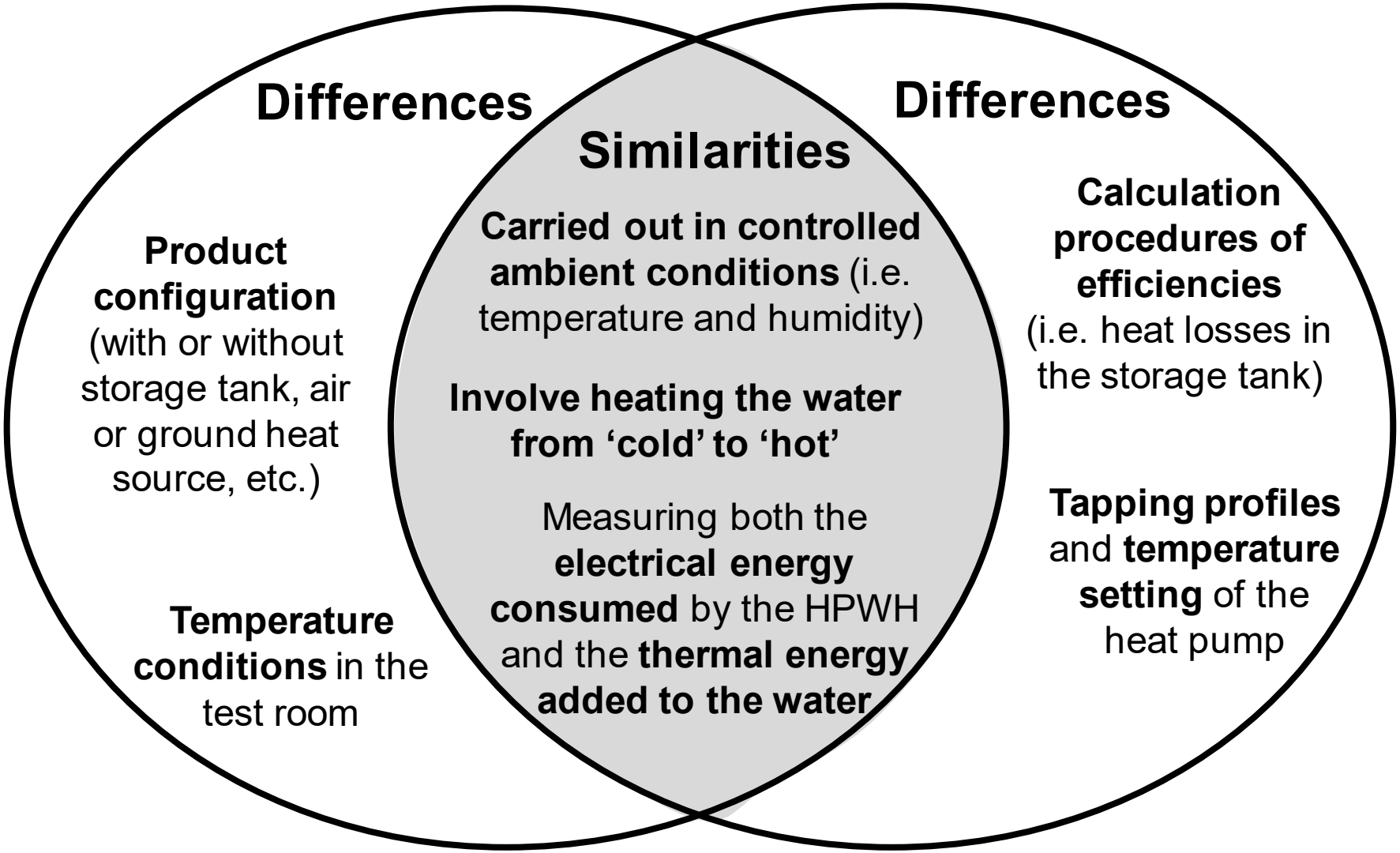
Major differences between test methods in use in different regions of the world



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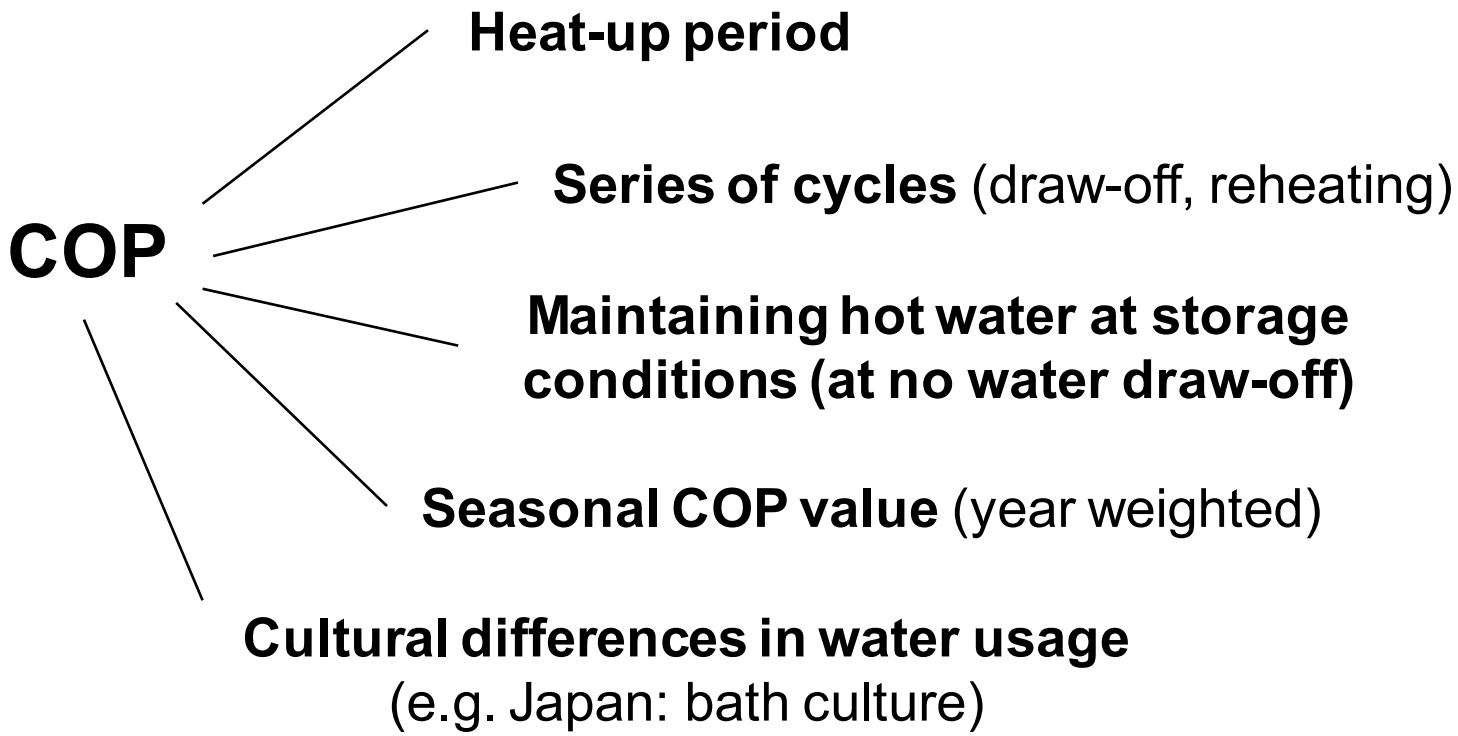
Major differences between test methods in use in different regions of the world



Draw-off schedules depend on the different standards

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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.

Is there an ideal form of harmonization ?

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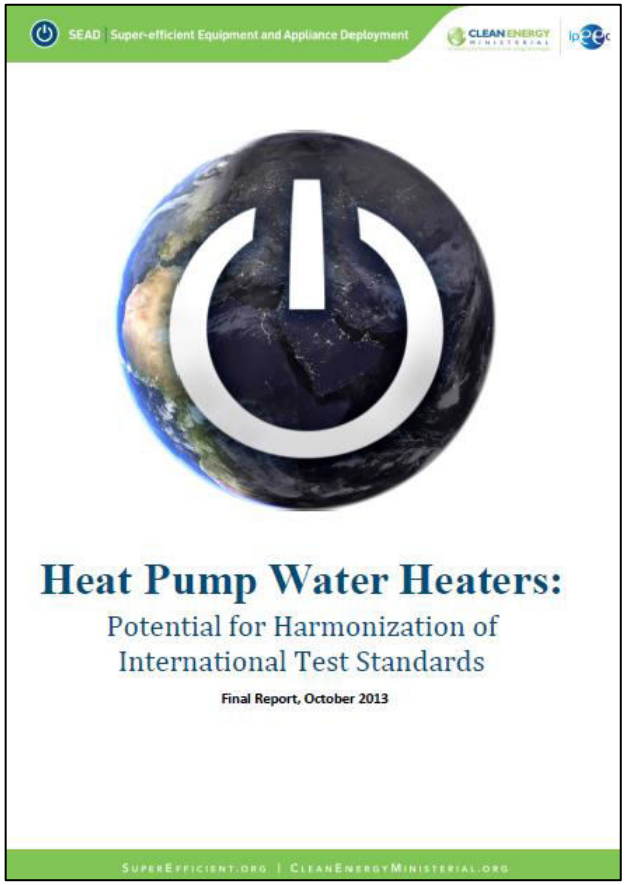
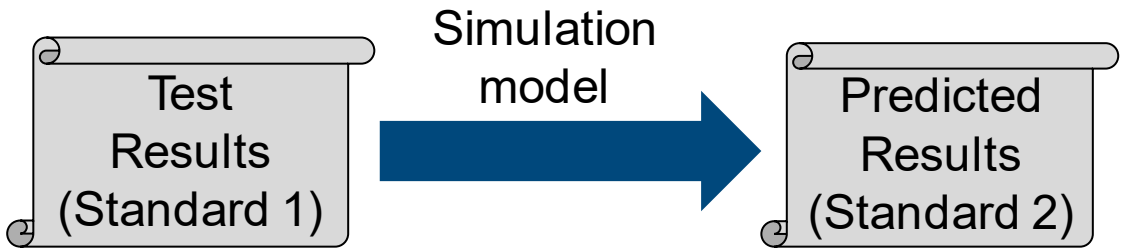
SEAD Report (2013): Potential for Harmonization of International Test Standards



"In an ideal form of harmonization, 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**."



ISO Draft Standard HPWH-19967-Part1-DIS

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ISO Working Group 12 on Heat pump water heaters of ISO Technical Committee 86/SC 6 proposed a **harmonization framework**, including **standardized physical tests** and a **staged development of simulation methods.**

Why Standards? 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 and RdSAP models in the UK with which the EPC for the building is calculated
- and also, **Heat Pump Associations develop models**

ISO Draft Standard HPWH-19967-Part1 and Part2

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ISO Working Group 12 on Heat pump water heaters **of ISO Technical Committee 86/SC 6** proposed a harmonization framework, including standardized physical tests and a staged development of simulation methods.

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.

A proposal of harmonized basic test conditions **for single mode DWH testing:**

- **Low-temperature** test condition of **7°C DB/6°C WB** – already in EU, Japan, Korea (draft), consistent with AS/NZS (<10°C), **Water temperature of 10°C**
- **Warm-temperature** test condition of **20°C DB/19°C WB** – already in USA, Canada, China, consistent with AS/NZS (18 to 20°C), **Water temperature of 15°C**
- **For models in frost conditions: test at 2°C DB/1°C WB**
- **For models in warm and humid climates: test at ~ 30°C and high humidity**

What are the next steps towards global harmonization?

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- **Challenge 1: How to handle innovative solutions / range of products**, e.g. 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.
- **Challenge 2: Harmonize the nomenclature of systems**
- **Challenge 3: Have a clear definition of performance**
- **Challenge 4: Set guidelines for harmonization**
  - 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 (e.g. electric, gas fired, HP, tankless etc.)

Discussion points on test procedures:

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- **How to rate air source DHW HP's in different climatic conditions**, when the HP's are tested at only one temperature?
  - ...
- **Smart control also effects manufacturers to let air source systems run during the day**, when higher temperatures are available
  - ...
- In test procedures **different combinations of heat pump and storage tank** (size) are considered as different heat pumps to be tested individually. **Why not separate these and combine through a calculation module?**
  - ...
- Should the **temperature of the storage tank** be fixed at a certain level in agreement with the demands for legionella?
  - ...

Thank you
for your attention

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May, 16-17, 2019, Seoul, South Korea

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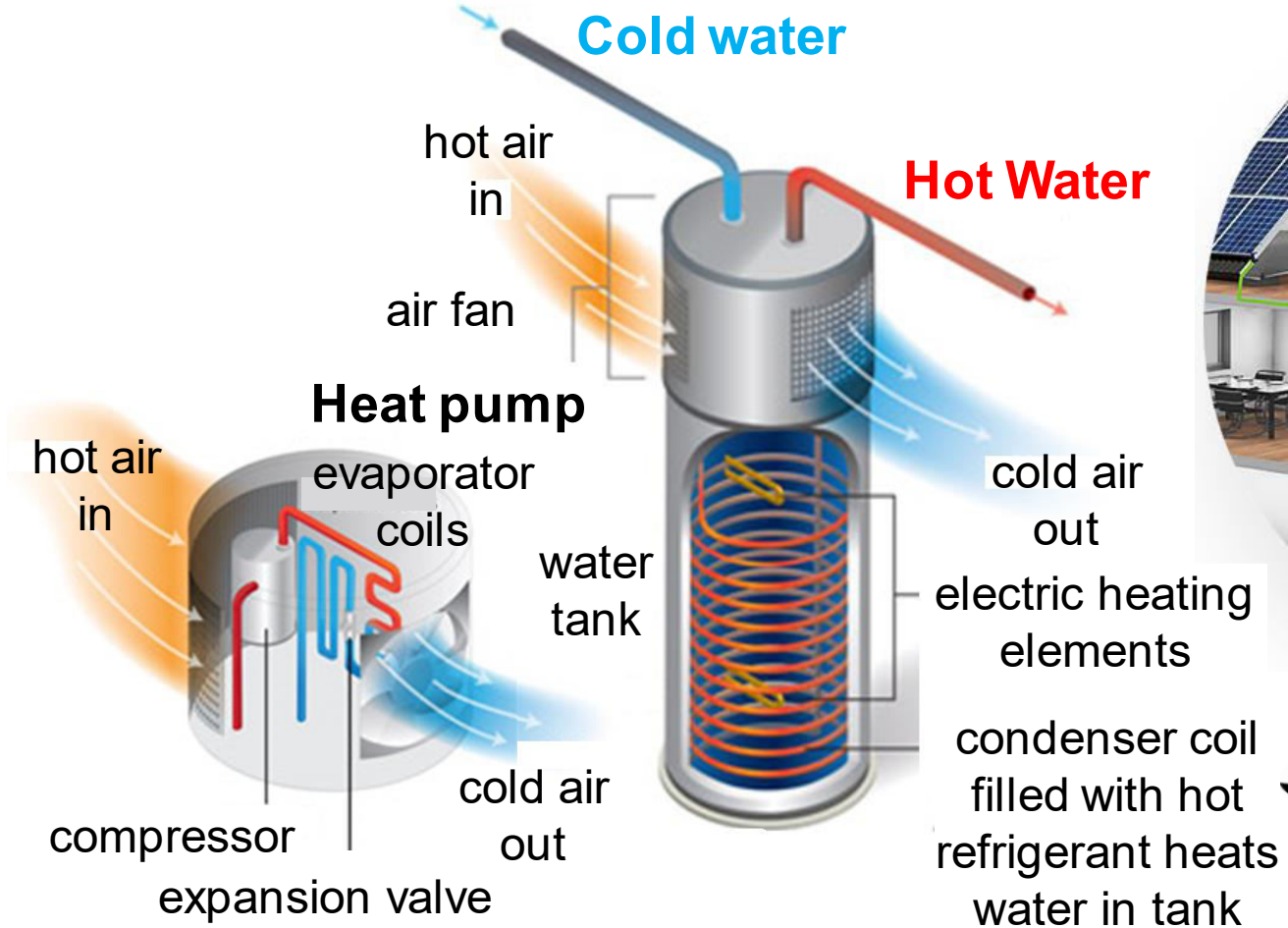
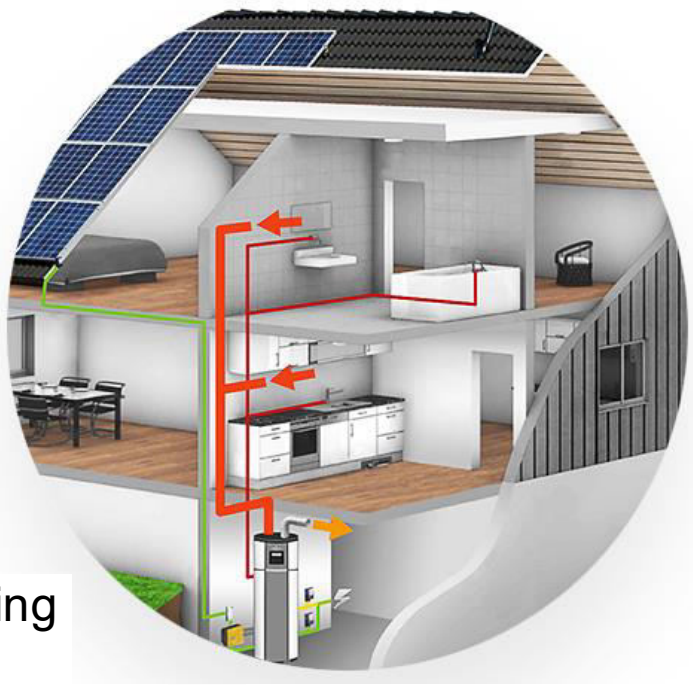
What is a Domestic Hot Water Heat Pump?





Function:
It uses the thermal energy from the air to heat up the domestic hot water

(www.bgesmartenergy.com)
(www.oekoboiler.com)

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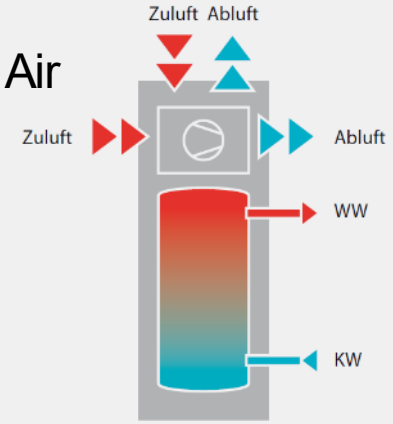
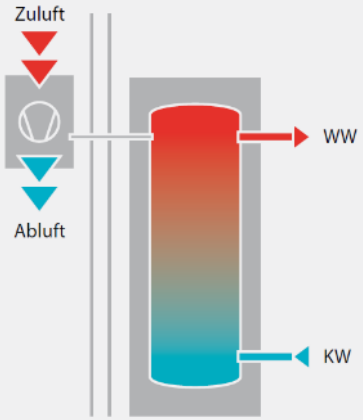
DHW heat pumps in Swiss single family houses – Typcial Systems

Compact

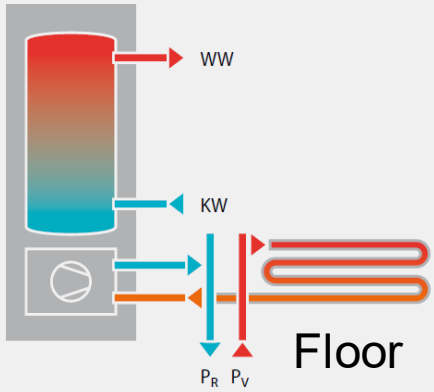
Air

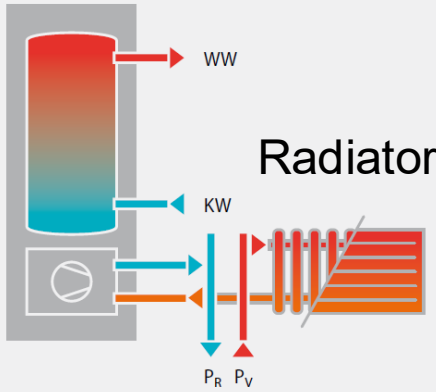


Split

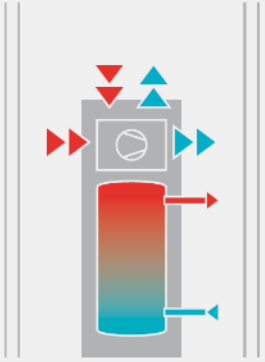


Combined with space heating

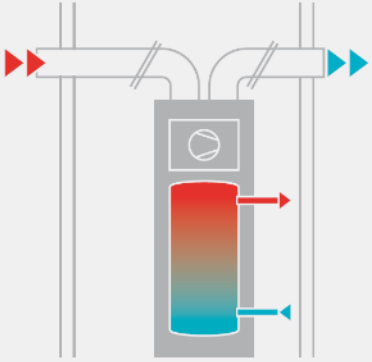


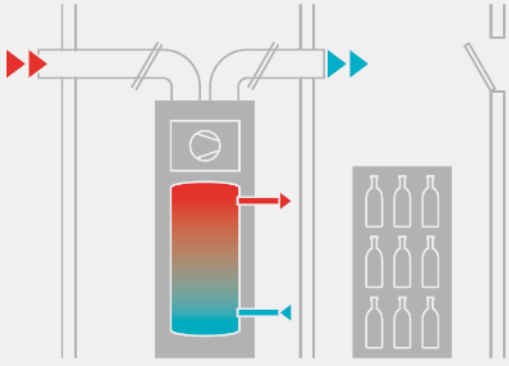


Indoor air

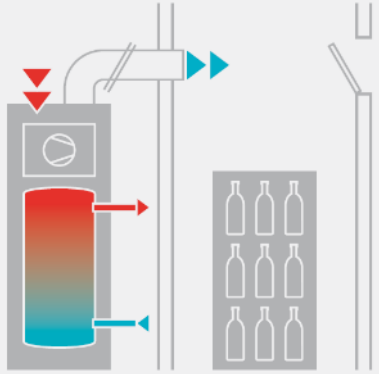


Duct systems using fresh air





indoor air



(Source: Merkblatt für Planer, GebäudeKlima Schweiz, Juni 2017)