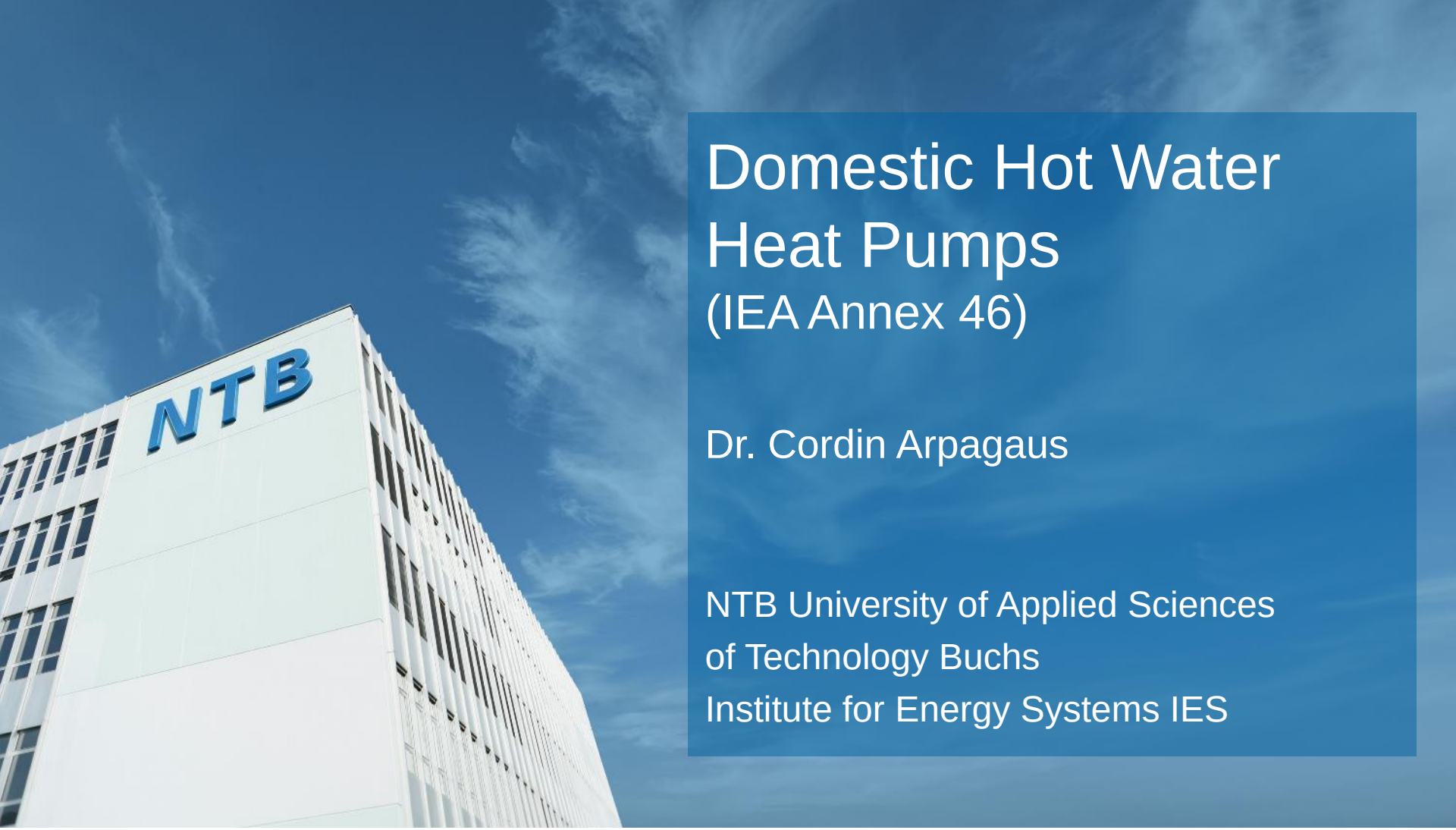

Domestic Hot Water Heat Pumps
(IEA Annex 46)

Dr. Cordin Arpagaus

NTB University of Applied Sciences of Technology Buchs
Institute for Energy Systems IES

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IEA Networking Event Switzerland

October 30th, 2018, Hotel Beaulac, Neuchâtel

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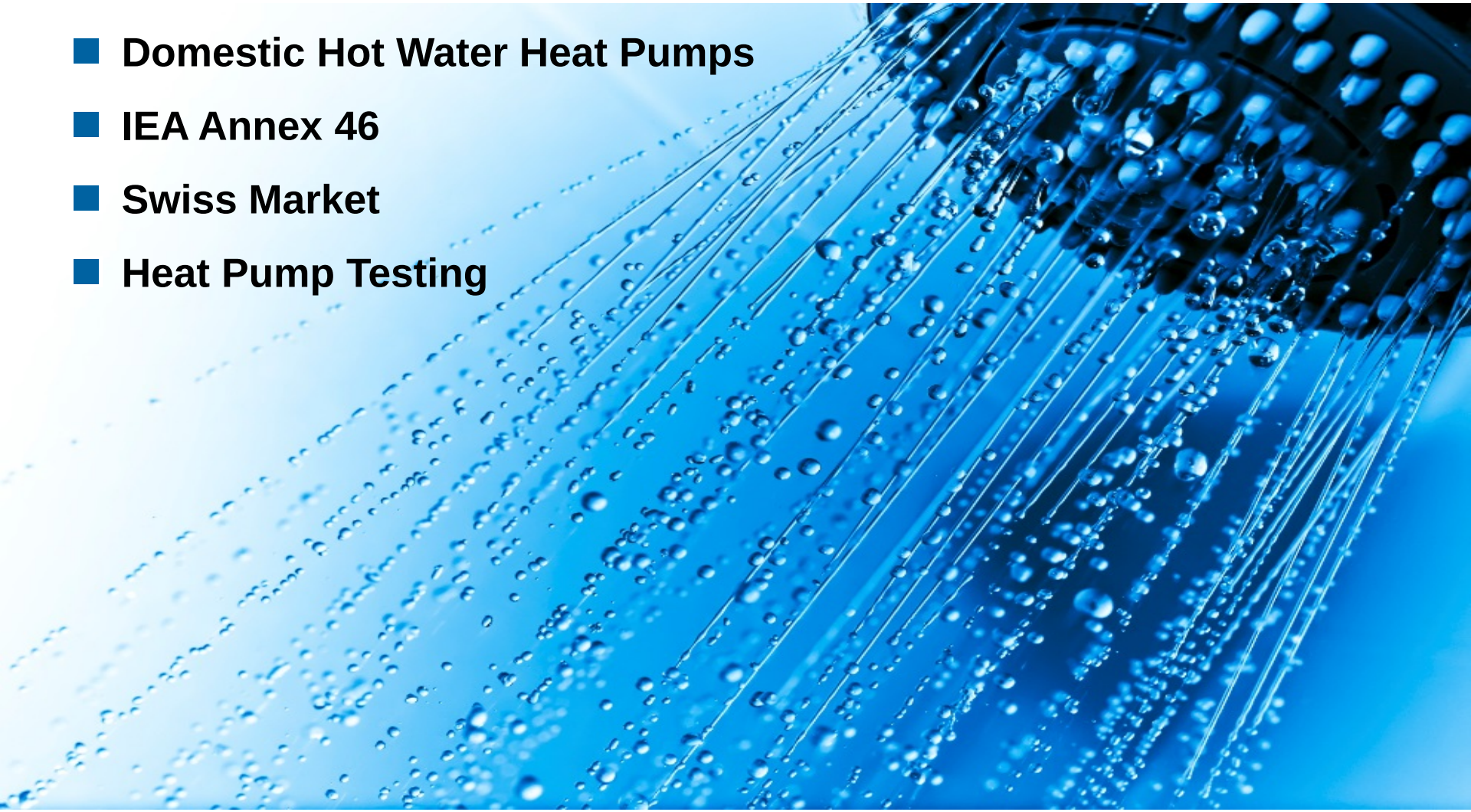

- Domestic Hot Water Heat Pumps
- IEA Annex 46
- Swiss Market
- Heat Pump Testing

What is a Heat Pump?

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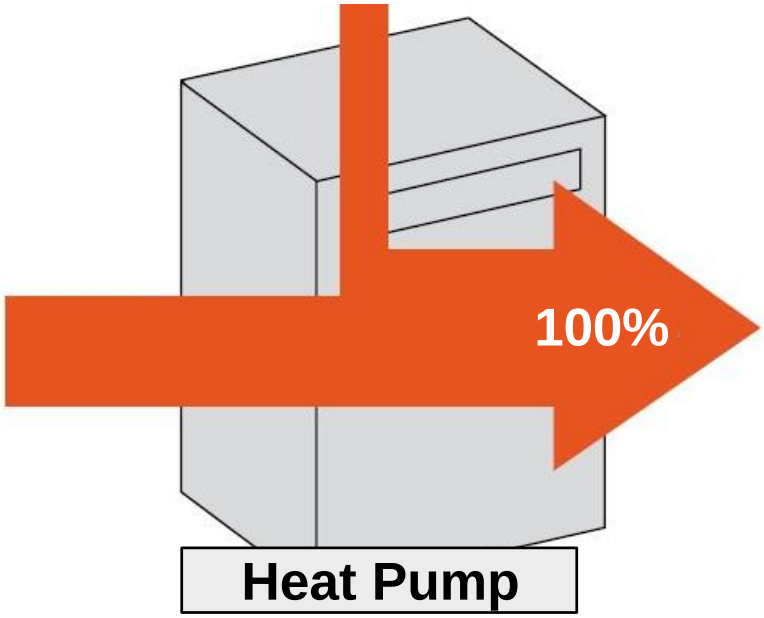
Evironmental heat

75%

Electrical power 25%



Heating and Hot Water

- 2/3 Air / Water Heat Pumps
- 1/3 Brine / Water Heat Pumps

$$COP = \frac{Thermal\ heat\ (kW)}{Electrical\ input\ power\ (\mathrm{kW})} \approx 4$$

COP: Coefficient of Performance

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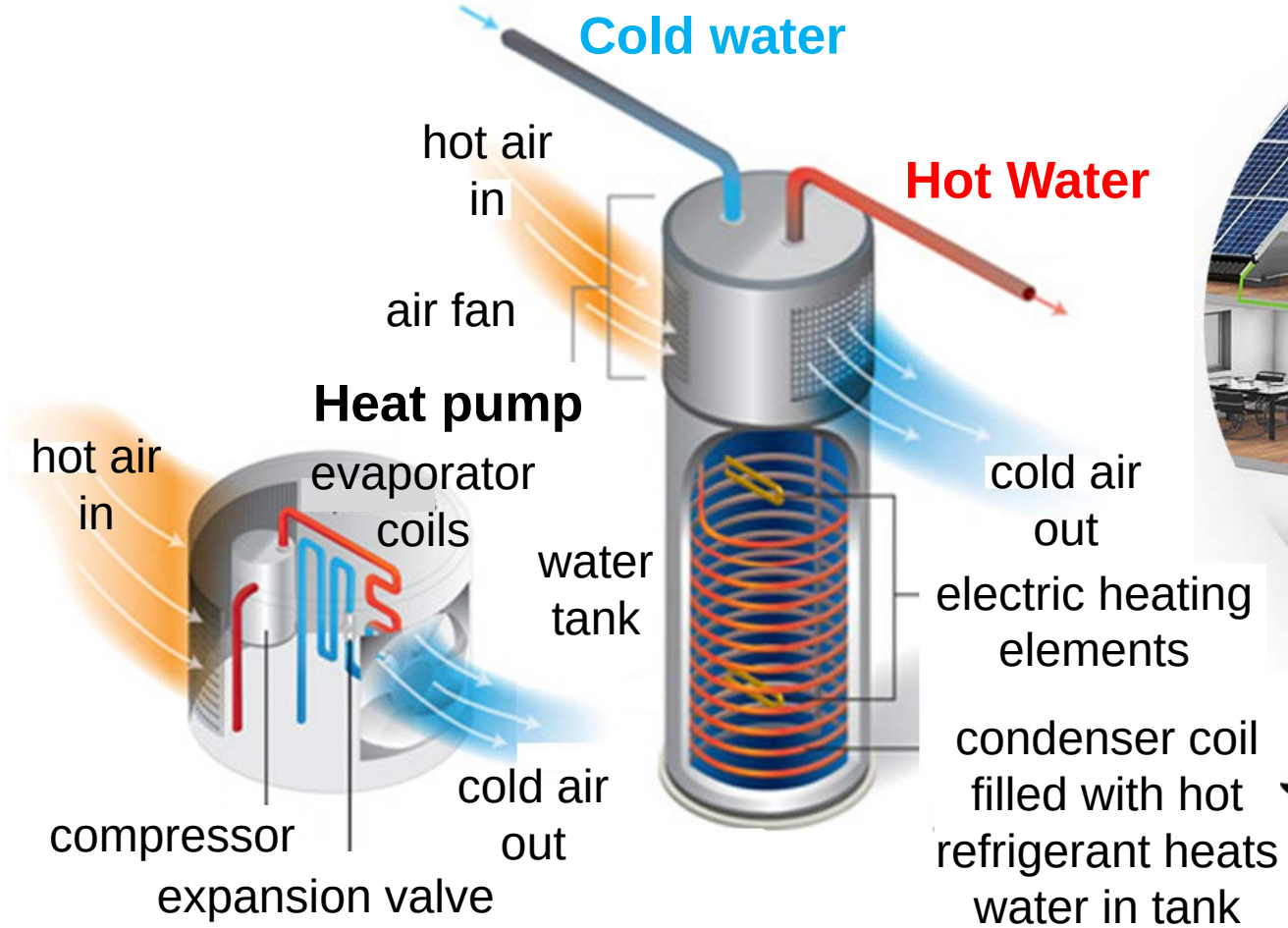
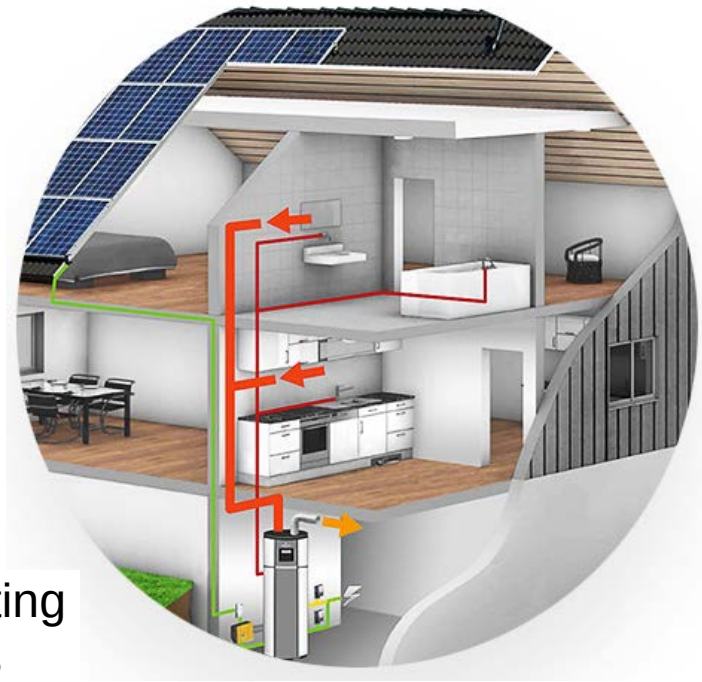
What is a Domestic Hot Water Heat Pump?





condenser coil filled with hot refrigerant heats water in tank

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

cordin.arpagaus@ntb.ch
(www.bgesmartenergy.com)
(www.oekoboiler.com)

DHW heat pumps in Swiss single family houses

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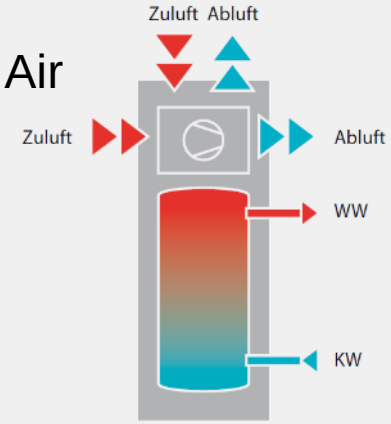
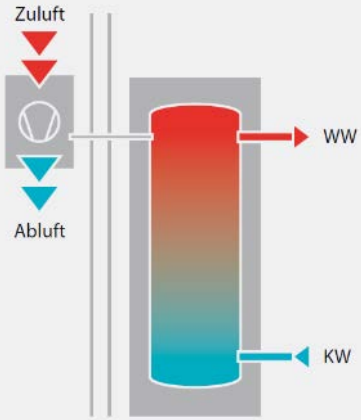
Compact

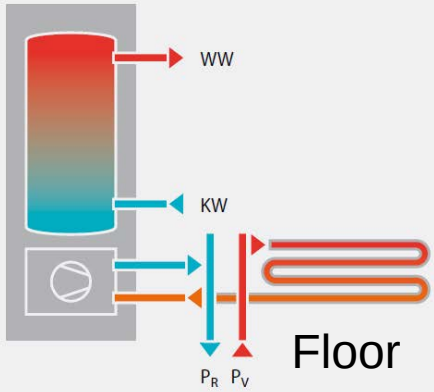
Air

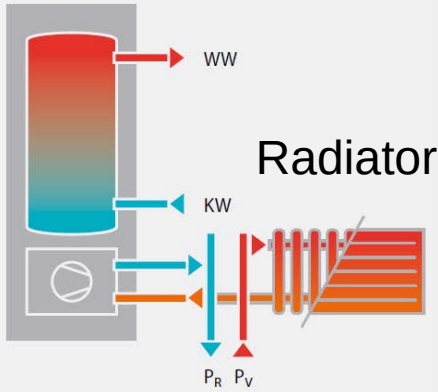


Split

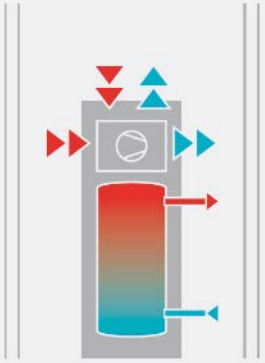


Combined with space heating

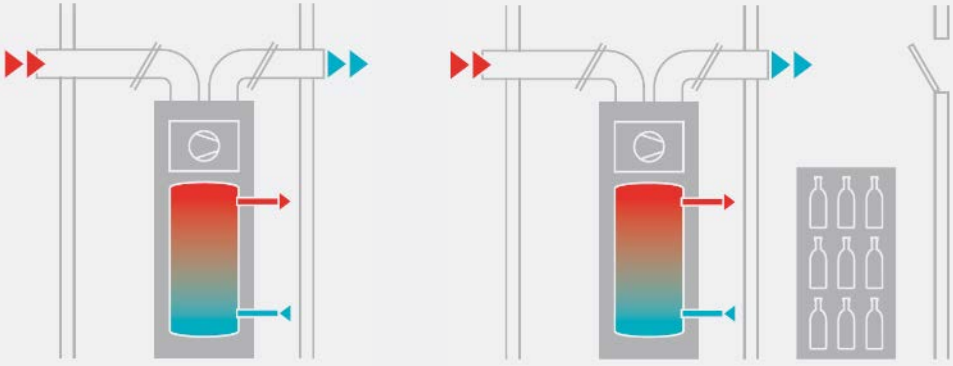




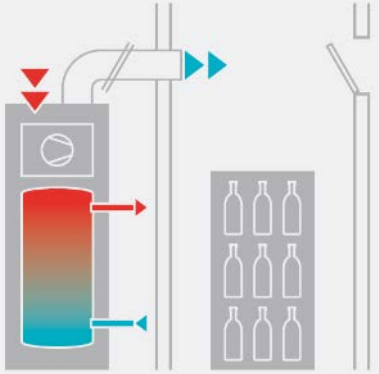
Indoor air



Duct systems using fresh air



indoor air



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

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Domestic Hot Water supply with Heat Pumps in multi-family houses

Conventional recirculation implemented in reference building

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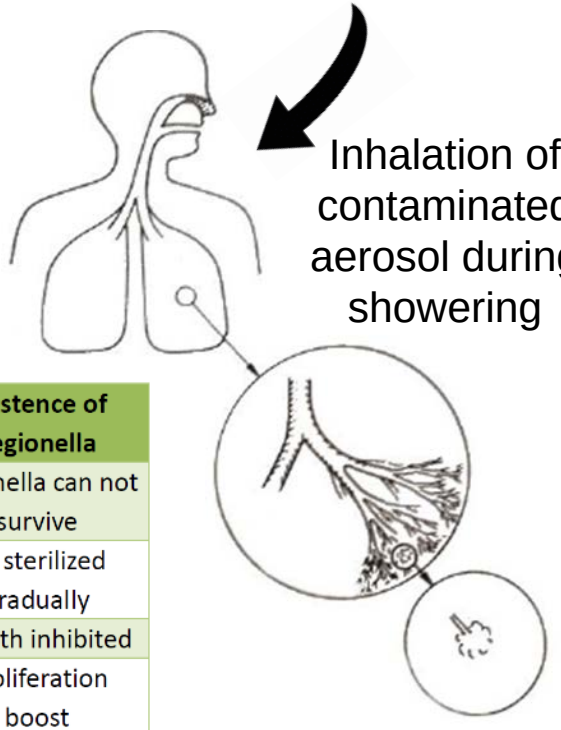
Water quality topics, such as legionella, are regulated in the standards SIA 385/1 and SIA 385/2

- SIA 385/1: basic requirements for DHW systems
- SIA 385/2: calculation methods for the planning of DHW systems

Legionella prevention (in single and multiple family buildings, "low risk"):

- DHW of 25°C to 50°C not used during the last 24 h must be thermally disinfected (recommendation is 1 hour at 60°C)
- The design of the DHW system requires:
  - 60°C at the storage tank outlet
  - 55°C at the heat traced pipes
  - 50°C at the tapping point



Temperature (°C)	Existence of Legionella
>60	legionella can not survive
55-60	be sterilized gradually
50-55	growth inhibited
20-50	proliferation boost
0-20	very few

European Technical Guidelines published in June 2017 as a draft (not yet harmonized)

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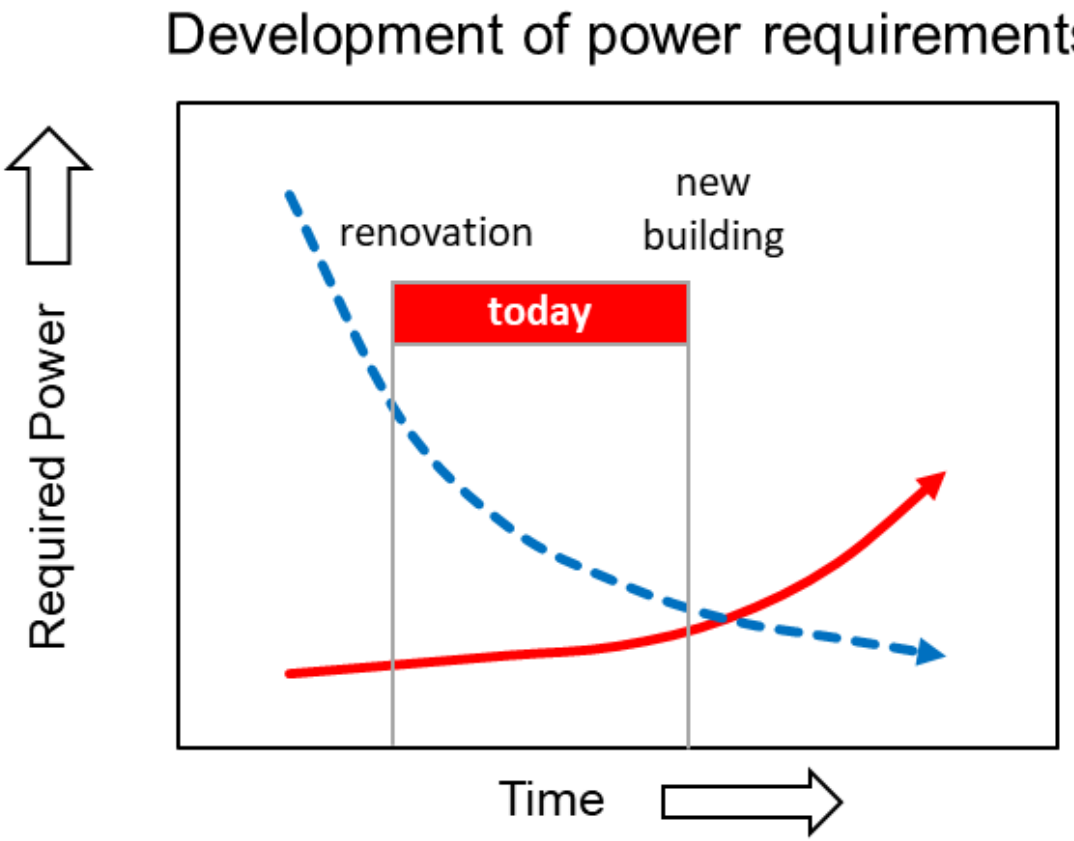
In a policy towards “zero energy houses” domestic hot water becomes the dominant energy factor!

Energy efficiency & CO_2 reduction



Domestic Hot Water

(higher comfort, e.g. showering, bathing)

Heating

(better thermal insolation, MINERGIE building standards)

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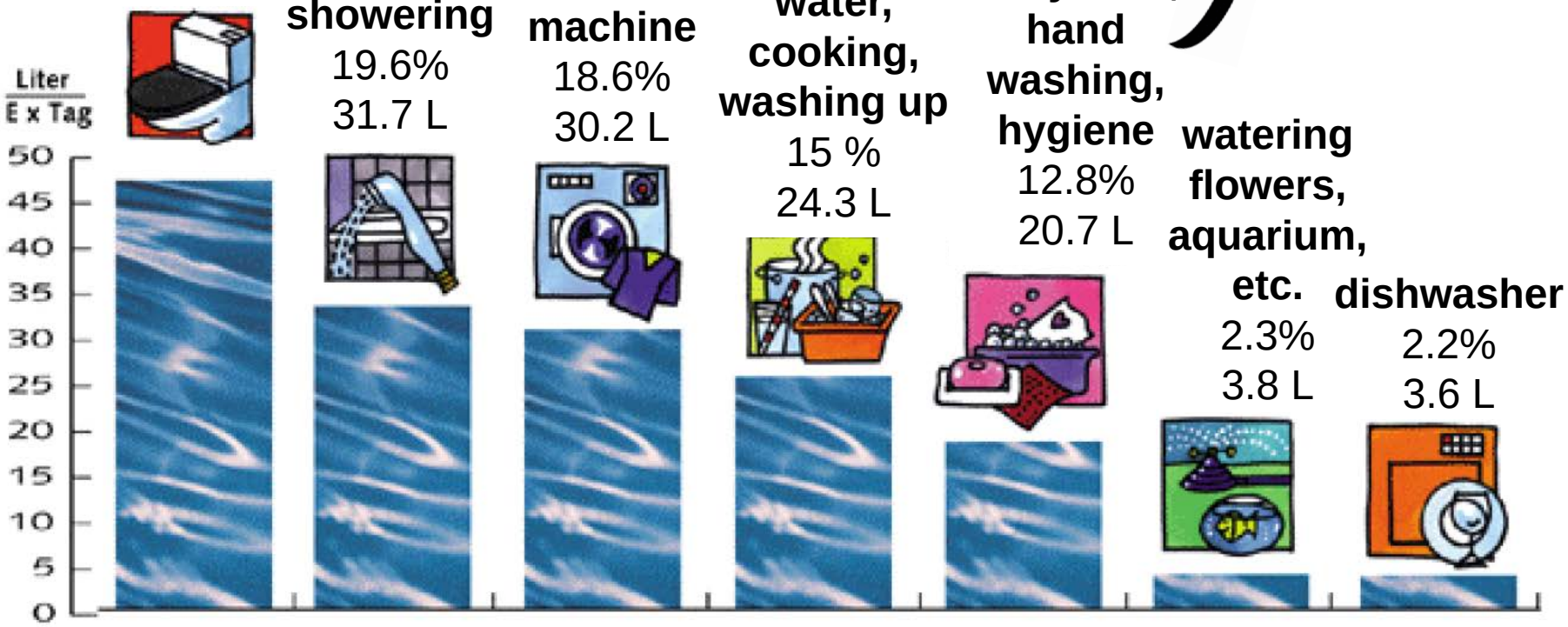
Average water consumption is about 162 liters per person per day

Rough estimation hot water:
+ bathing/shower (50% of 31.7)
+ dish washing by hand (50% of 24.3)
+ personal care (50% of 20.7)
= 38.4 L/d per person



(Schweizerischer Verband des Gas und Wasserfaches SVGW, 2016, www.svgw.ch)

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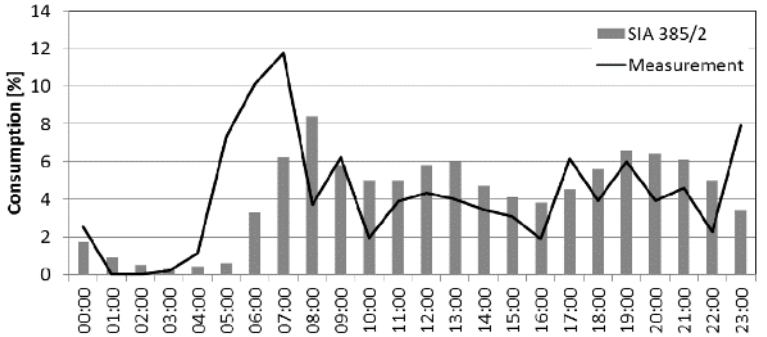
Field measurement data in different buildings indicate about 35 to 45 L/d per person

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

Hot water consumption profile

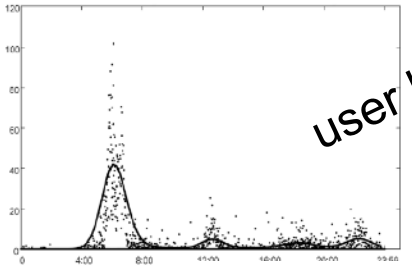


(Vetsch et al. 2012)

Hot water demands according to standard SIA 385/2

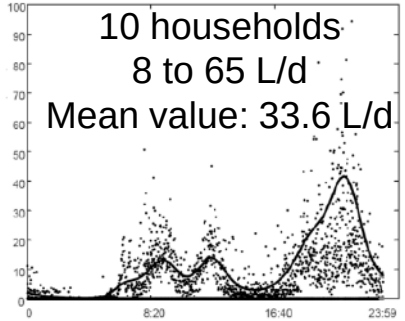
Building type	Note	Domestic hot water consumption in standard liter per day: average demand per person	maximum demand per person
Single family house, condominium	simple standard	**40**	50
	normal standard	45	60
	high standard	55	70
Multiple family building	simple standard	**35**	45
	high standard	45	60
The bold marked values are used for rough dimensioning			

Morning consumers



user behavior

Evening consumers



(Heim et al. 2012)

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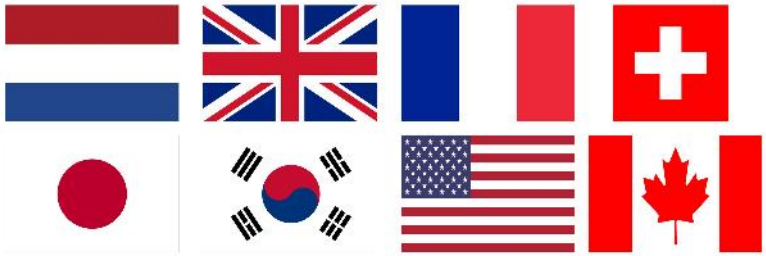
International project on heat pumping technologies for Domestic Hot Water under the IEA Technical Collaboration Program for Heat Pumping Technologies (TCP-HPT)

HPT-Annex 46
Domestic Hot Water Heat Pumps



Project start: 1st of January 2016
Project end: 30th of September 2019

Website: www.hpt-annex46.org

- Canada (Natural Resources Canada)
- France (EDF R&D)
- Japan (Waseda University)
- Netherlands (Phetradico = Operating Agent)
- South Korea (Korean Refrigeration and Air Conditioning Assessment Center)
- Switzerland (NTB Buchs)
- UK (Ulster University)
- USA (Oakridge National Laboratories)

Tasks & Objectives:

- Task 1 – Market overview
- Task 2 – Systems and concepts
- Task 3 – Modeling
- Task 4 – R&D
- Task 5 – Example projects
- Task 6 – Communication

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Lessons learned so far

- **European markets:** Trend to combined systems (space heating and hot water) and reduction of the energy consumption (zero energy houses), integration of heat pumps in smart-grids (SG-Ready)
- **Scandinavian countries:** Low-temperature district heating systems with local booster heat pumps to increase the temperature to 60 to 65°C to prevent legionella
- **UK:** Major housing stock supplied by central heating systems fired by natural gas or oil
- **North America:** Split systems for space heating/cooling and hot water heating, both gas fired and electrically heated
- **Asia:** Very diversified markets, strong growth in China of both solar heated and heat pump heated DHW systems
- **Korea:** still at the start for DHW heat pumps, promising market in district heating
- **Japan:** CO_2 heat pump water heater (ECO Cute) is leading the Japanese market (since market introduction in 2001 > 5 Mio units shipped), Japanese bathing culture: average water consumption 300 L/d per person, hot water consumption (at 40°C) is about 110 L/d per person
- **Heat pump manufacturers** are aware of the refrigeration challenges due phase-down of R134a. Potential replacement refrigerants are: R290 (propane, GWP=4, highly inflammable A3), R1234yf (HFO, GWP=20, lightly inflammable A2L)

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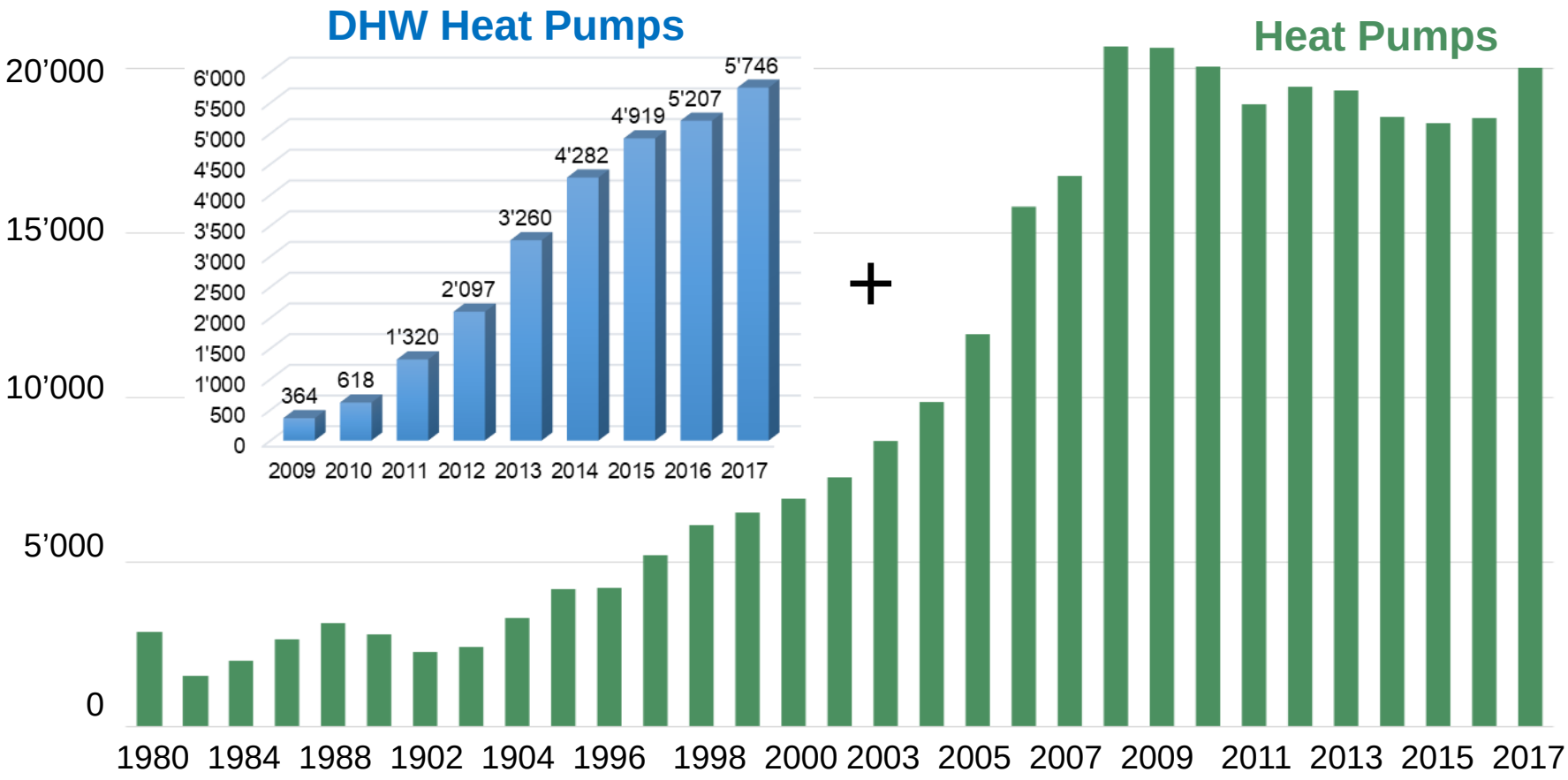
Heat pumps are key technology in the energy transition
Domestic Hot Water Heat Pumps: 5'746 units in 2017



Energy source (2017):

- 69% Air/Water Heat Pumps
- 29% Brine/Water
- 2% Water/Water

- 240'000 heat pumps in operation
- 80% of new homes are equipped with heat pumps

FWS Fachvereinigung Wärmepumpen Schweiz

Hot water heat pump boiler

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Air/water heat pump boiler

(Cipag AG)

(Styleboiler / Tobler)

Commercially available heat pump boilers

Description	Range	Average value
COP at A20/W10-55	3.2 to 4.0	3.6
COP at A15/W10-55	2.9 to 3.6	3.2
Sales price	2’850 to 5’400 CHF	3’733 CHF
Noise level	50 to 67 dB	60 dB
Storage volume	200 to 450 Liter	277 Liter
Electrical backup heating	1.0 to 3.0 kW	1.7 kW

Refrigerant: R134a (WPZ, 2017)

(31 suppliers and 78 models, www.topten.ch, Oct. 2016)

Outdoor unit of split-system (Vailland Schweiz GmbH)

WPZ Wärmepumpen-Testzentrum → Test results

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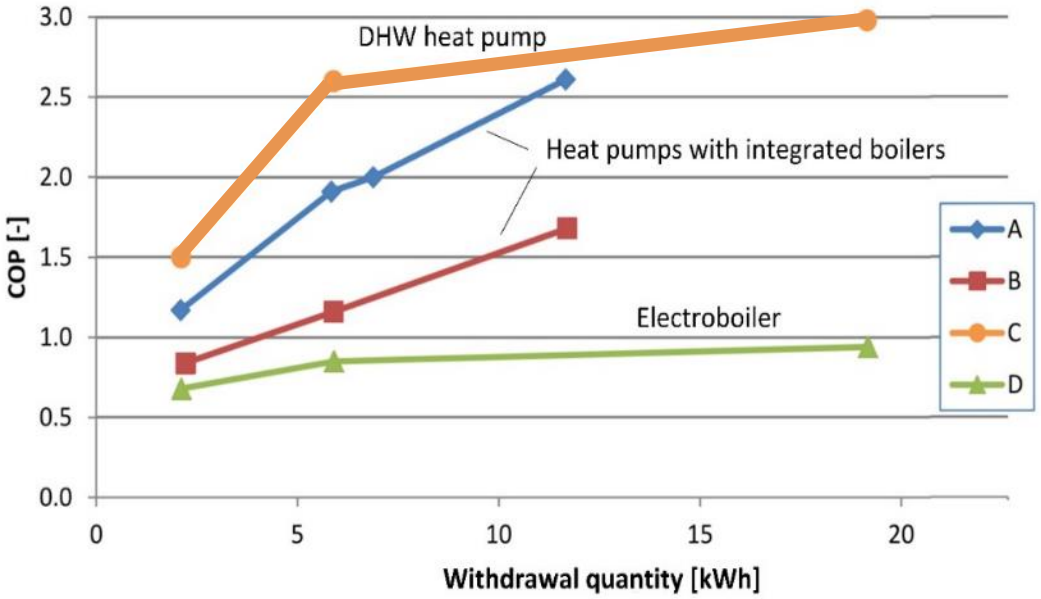
Efficiency (COP) comparison of a DHW heat pump with heat pumps with integrated boilers and an electroboiler



DHW heat pump is 3x more efficient than an electroboiler

(Data from the WPZ heat pump test center at NTB Buchs)

(Eschmann, 2015)

		COP			
Withdrawal profile	Withdrawal quantity [kWh]	A Heat pump with integrated boiler (175 L)	B Heat pump with integrated boiler (260 L)	C DHW heat pump (270 L)	D Electroboiler (300 L)
S	2.1	1.17	0.84	1.50	0.68
M	5.8	1.91	1.16	2.60	0.85
Praxis 1	6.8	2.00	-	-	-
L	11.7	2.61	1.68	-	-
XL	19.1	-	-	2.98	0.94
Heat losses [W]		42	60	27	63

Since 2009, electroboilers are forbidden in Switzerland

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- The EFFIBOILER program of “Energie Zukunft Schweiz” promotes the replacement of old electroboilers to new heat pump boilers with a contribution of 450 CHF.
- For example, in the canton St. Gallen the contribution is even 1’000 CHF.
- The program is supported by the promotional program ProKilowatt under the direction of the Swiss Federal Office of Energy.

Cost comparison: Electroboiler vs. Heat pump water heater

Hot water temperature 55°C	Unit	Electroboiler (300 L)	Heat pump Water heater
Annual energy consumption	kWh/a	4’500	1’500
Investment costs	CHF	2’000	4’500
Amortization (15 years)	CHF	133	300
Interest rate 4%	CHF	40	90
Operating costs (0.14 CHF/kWh)	CHF	630	210
Annual costs	CHF	803	600

(GebäudeKlima Schweiz, 2012)

DHW heat pumps (heat pump boilers) with FWS certification

36 heat pump suppliers and >120 models identified

Manufacturer	Model types
Alpha innotec	BWP 307, BWP 307S, BWP 261 (S), BWP 262 V4A
Apitec AG	DHW300, DHW300+, DHW300d, DHW300d+, DHW400+
Atlantic Suisse AG	WPA 303 ECO, Explorer 270L FS, Explorer 270L Cozytouch, WP-B 300
Atlis AG	Heatmaster CH-301
Berger Boiler Service	AE WPA 303 ECO 300 Liter
Buderus Heiztechnik AG	DHW300, DHW300+, DHW300d, DHW300d+, DHW400+
Cipag SA	Cipag Nuos Monobloc 250 (see Domotec AG), Cipag Nuos Monobloc 250 SOL, AQUANEXT PLUS 200, AQUANEXT PLUS 250, AQUANEXT PLUS 250 SYS
Coolstar AG	CSWB300L
CTA AG	CBE WP 300 Eco, CBEW WP 300 Eco, CVBE WP 300, 400, CMBE WP 260
CTC Giersch AG	CTC EcoWater300, EcoWater301, EcoWater302, CTC EcoWater WP-LS 300 Liter
Delta Solar GmbH	WP-LS-E 300, WP-LS-V 270
Domotec AG	SWPL 250, SWPLW 250, NUOS II S 200, NUOS II S 250, NUOS II S 250W1, NUOS II S 250 W2, HPWH 250 SOL
Elcotherm AG	Aerotop DHW 200, Aerotop DHW 250, Aerotop DHW 250SYS
Energie Est, Ida	Eco 250esm, AquaPura Split 250
Energo AG	SOWAPU-300I-13C
Glen Dimplex Deutschland GmbH	BWP 30 HM
Grünenwald AG	BWW 300, BWW 301 25.09.2014
Heim AG Heizsysteme	WPB-300 ECO, WPB-300 ECOplus, WPB-500 ECO
Hoval AG	CombiVal WPE 300, CombiVal WPER 300
Kibernetik AG	WPLW-KIB-BW-300L, WPLW-KIB-BW-300L-S, F1, F1 WT
Makscom GmbH	RS-3.6FAD/300L
MHG Heiztechnik (Schweiz) GmbH	VT 3130, VT 3131, VT 3132
Nibe Wärmetechnik	MT-WH 2029-F, MT-WH 2029-1FS
Ochsner Wärmepumpen GmbH	Europa 250 DK/DKL, Europa 323 DK
Proftech International GmbH	Kolant KL-300-S
Peter Wärmepumpen GmbH	Heatmaster AP 304, Heatmaster AP 304 S, HeatMaster AP 307, HeatMaster AP 307 CT, HeatMaster AP 452
Stiebel Eltron AG	WWK 300, WWK 300 SOL, WWK 300 electronic CH, WWK 300 electronic CH SOL
Swisstherm AG	VT 167, VT167 OHE, VT167E, SWT Eco
TCA ThermoClima AG	OH-BWWP270-0, OH-BWWP270-1, OH-BWWP270-2
Termo-Tehnika, d.o.o	TC2 VZRT/E-321 ECO NT
Meier Tobler AG	FUTURA I T SWP S II 300, I T SWP SW II 300, I T SWP SWW II 300, I T SWP SX 300, I T SWP SWX 300, I T SWP SWWX 300, I T SWP S II 250, I T SWP SW II 250, I T SWP SWW II 250, I T SWP SX 250, I T SWP SWX 250, I T SWP SWWX 250
Vesttherm A/S	VT 3130, VT 3130
Viessmann (Schweiz) AG	Vitocal 161-A WWK 161.A02, Vitocal 161-A WWKS 161.A02
Walter Meier (Klima Schweiz) AG	TWH 300E, TWH 300EH
Weishaupt AG	WWP-T 300 WA
Windhager Zentralheizung Schweiz AG AquaWINAir	AquaWINAir AWA 270
TOTAL: → 36 heat pump suppliers	

Source (in alphabetic order): www.fws.ch/wp-content/uploads/2018/10/Guetesiegelliste_Warmwasser-WP.pdf

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Heat Pump Test Centre certified according to EN 17025 – Testing at high quality

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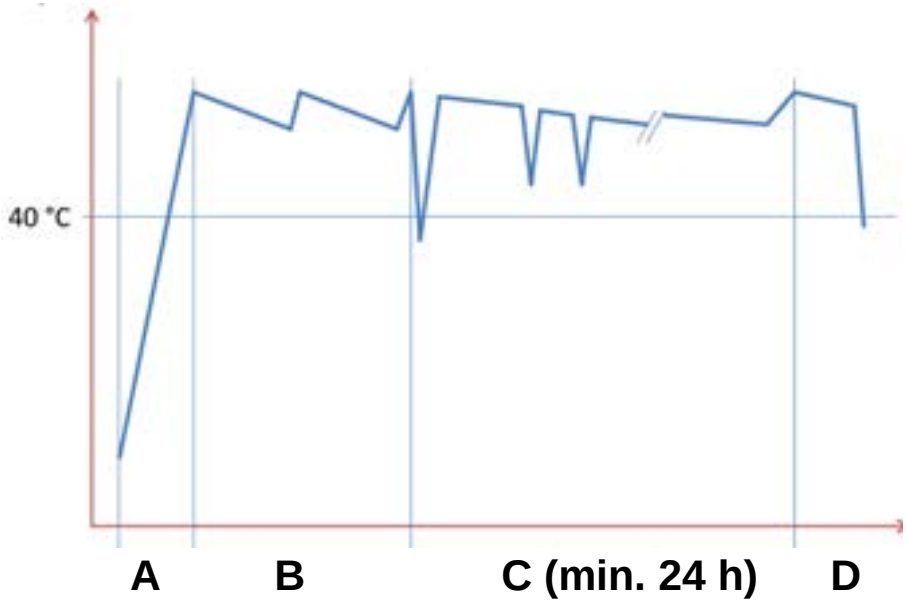
The heat pump test center WPZ follows the testing standard EN 16147 for DHW heat pumps

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



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

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

Warmwasser-Wärmepumpe GEPRÜFTE QUALITÄT

Mandatory in Europe since 2015

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Supplier and model

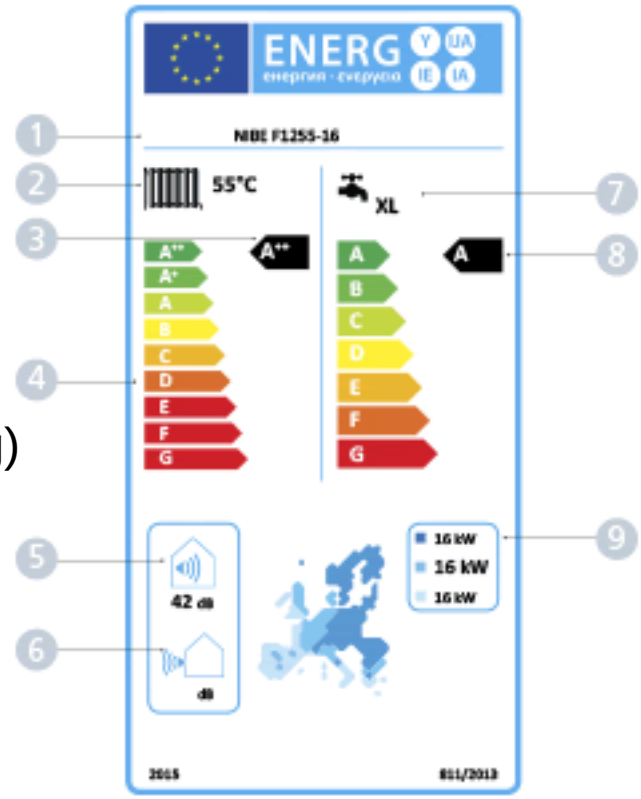
Heating

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).

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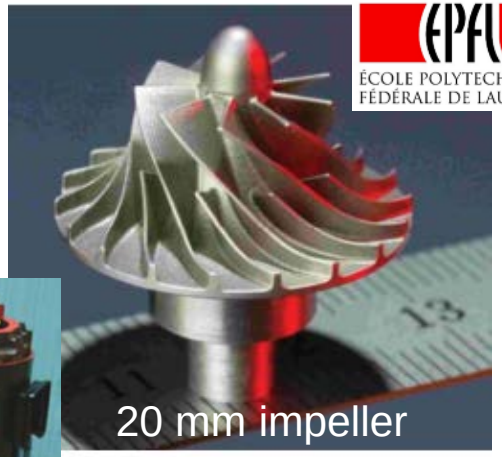
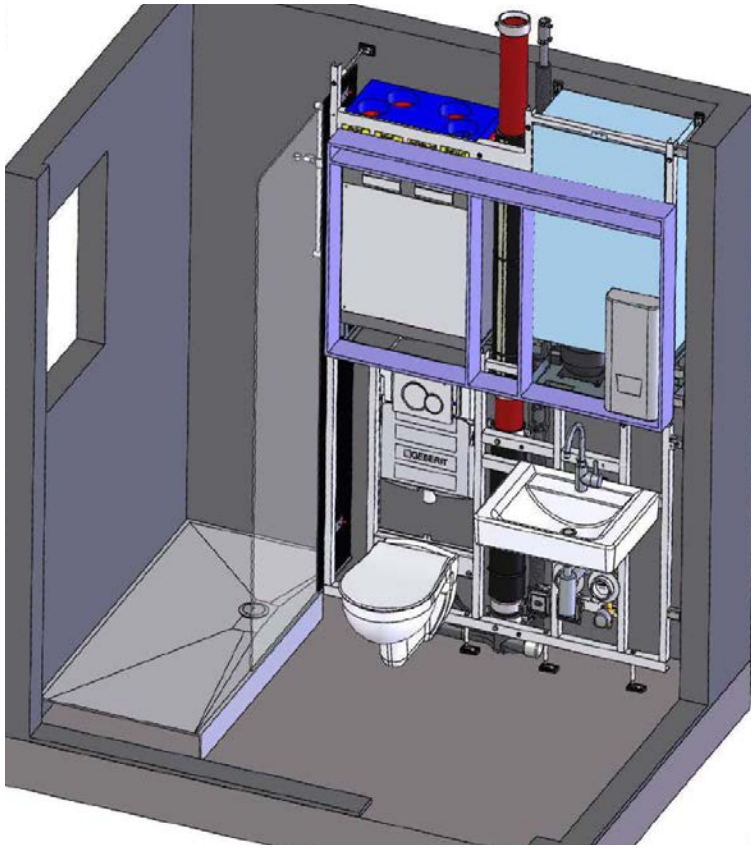
New compressor technologies, installer-focused technologies, and shift to natural refrigerants

- **Miniature turbo compressor for heat pump applications** (feasibility confirmed with R134a, isentropic efficiency of 0.8, gas bearings, high speed up to 240’000 rpm, oil-free, small weight, low noise)



Size comparison (Turbo vs. Scroll compressor)



- **Compact decentralized DHW supply system with small heat pump for front-wall installations of bathrooms** (THERMOS from Swissframe AG)
- **Heat pumps with natural refrigerants (CO_2, hydrocarbons) and low charge**

Further Information

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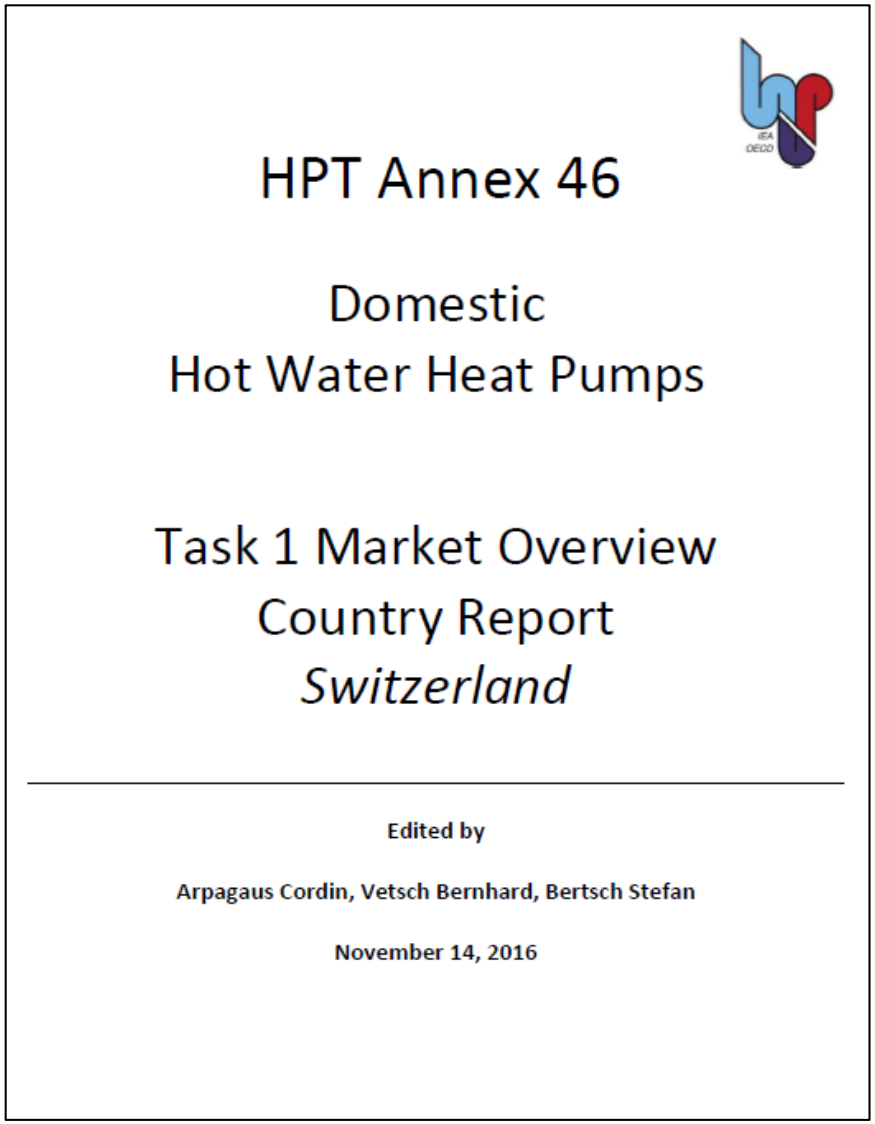


HPT Annex 46

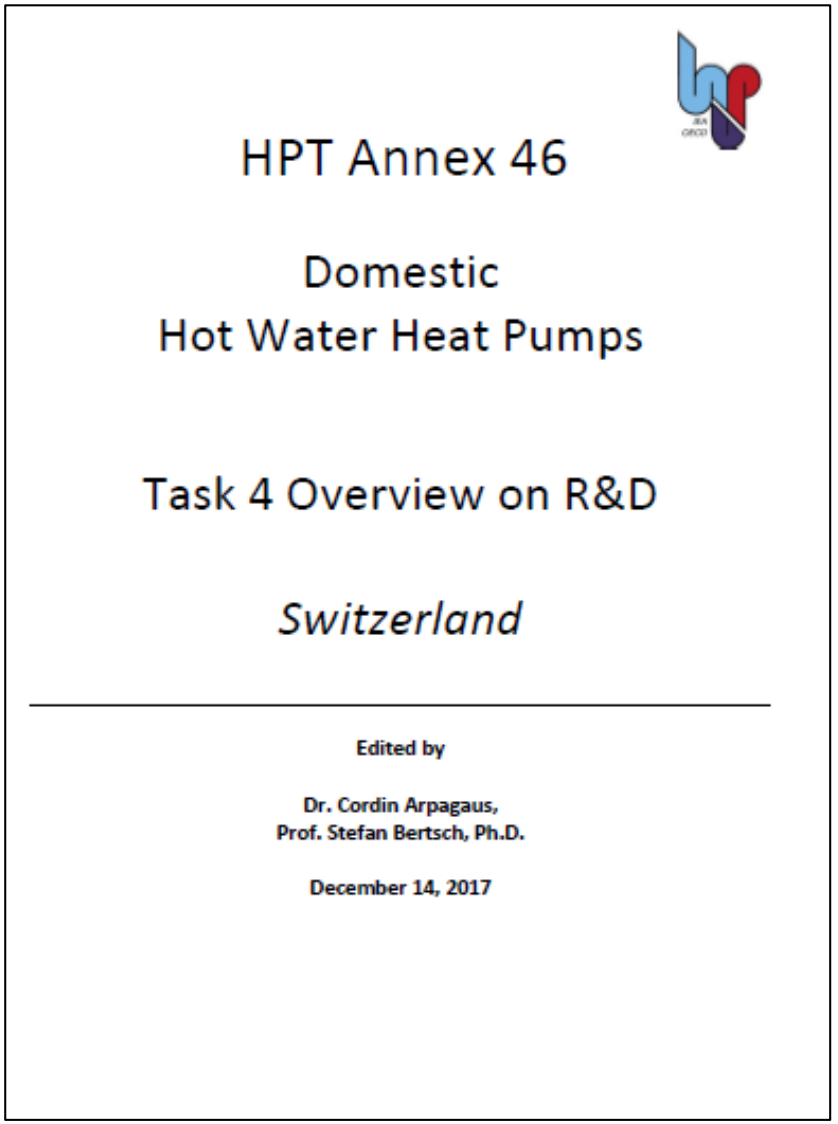
Domestic
Hot Water Heat Pumps

Task 1 Market Overview
Country Report
Switzerland

Edited by

Arpagaus Cordin, Vetsch Bernhard, Bertsch Stefan

November 14, 2016



HPT Annex 46

Domestic
Hot Water Heat Pumps

Task 4 Overview on R&D

Switzerland

Edited by

Dr. Cordin Arpagaus,
Prof. Stefan Bertsch, Ph.D.

December 14, 2017

Further Information

Gut zu Wissen

planer+installateur 06/07-18

IEA HPT Annex 46: Domestic Hot Water Heat Pumps

Der IEA HPT Annex 46 ist ein internationales Projekt im Rahmen des IEA Technical Collaboration Program for Heat Pumping Technologies (TCP-HPT) zum Thema Warmwasser-Wärmepumpen (WW-WP). Das Institut für Energiesysteme (IES) der NTB Buchs nimmt dabei im Auftrag des Bundesamtes für Energie die Ländervertretung der Schweiz wahr und informiert die Schweizer Fachbranche über die aktuellen Ergebnisse.

Dr. Cordin Arpagaus, Prof. Dr. Daniel Gstöhl, und Prof. Stefan Bertsch, PhD*

Nachhaltige Warmwasserbereitung mit Wärmepumpen wird zu einer weit verbreiteten Technologie in der Haustechnik und bietet intelligente Speichermöglichkeiten. Mit Wärmepumpen lässt sich Wasser sehr effizient erwärmen und der CO_2-Ausstoss reduzieren. Grosses Potential findet sich im Neubau sowie in der Sanierung beim Ersatz elektrischer oder ölbefeuerter Heizungen im Ein- und Mehrfamilienhaus. Smart-Grid-Anwendungen für die Optimierung der Speicherkapazität in Kombination mit Photovoltaik sind ebenfalls stark im Trend.

Ziel des Projekts

Das Hauptziel des IEA HPT Annex 46 (Bild 1) ist die detaillierte Analyse von Wärmepumpentechnologien für die Erzeugung von Brauchwarmwasser in den teilnehmenden Ländern, sowohl im Hinblick auf den Markt als auch auf den Forschungsstatus. Teilnehmer-Länder sind die Niederlande (Operating Agent), Grossbritannien, Frankreich, die Schweiz, Japan, Südkorea, Kanada, und die USA. Es werden sowohl zentrale als auch kombinierte Warmwasser-Wärmepumpen-Systeme betrachtet. Die gewonnenen Informationen werden strukturiert aufgearbeitet, um bei Endverbrauchern und politischen Entscheidungsträgern ein besseres Verständnis zu erzielen.

Arbeitspakete – Tasks

Die Arbeiten sind in sechs Arbeitspakete (Tasks) gegliedert. Im Task 1 erstellt jedes teilnehmende Land eine aktuelle Marktübersicht. Besonderes Augenmerk liegt dabei auf den geltenden Normen und Standards zur Warmwassererzeugung, den Massnahmen zur Vermeidung von Legionellen, den Statistiken zum Warmwasserbedarf, den Entwicklungsarbeiten sowie auf der Identifizierung von Markttrends.

Der Task 2 untersucht verschiedene Konzepte und Systeme, um einen objektiven Vergleich mit anderen Technologien zu ermöglichen. Verteilungsverluste sind dabei besonders bei Mehrfamilienhäusern (MFH) von grosser Bedeutung.

Im Task 3 geht es um die Modellbildung. Die Aufgabe konzentriert sich auf die Erstellung eines validierten Berechnungsmodells zum Vergleich von verschiedenen WW-WP mit Speicher und Temperaturschichtung.

Task 4 widmet sich der Forschung und Entwicklung. Obwohl es bereits zahlreiche WW-WP-Produkte auf dem Markt gibt (etwa 80 WP-Boiler-Modelle in der Schweiz von über 30 Lieferanten, topten.ch), geht es hier darum, Innovationen zu erkennen und das Wissen über den aktuellen Stand der Technik und zukünftige Technologien international auszutauschen.

Der Schwerpunkt im Task 5 liegt auf der Suche nach Beispielen und Monitoring-Projekten, um die Modelle (soweit möglich) zu validieren und um Marktbeispiele für die Kommunikation (Task 6) zu erstellen. Verbrauchsdaten werden zum besseren Kundenverständnis gesammelt. Schliesslich wird eine Website erstellt, welche die gewonnenen Erkenntnisse öffentlich zugänglich macht.

HPT-Annex 46

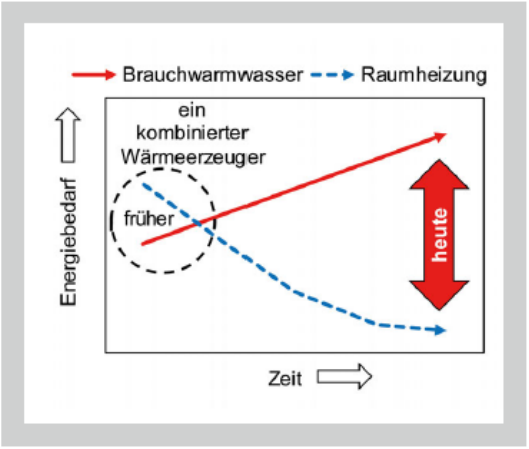
Projektstart: 1. Januar 2016
Projektende: 30. September 2019

Link auf Website:
www.hpt-annex46.org

Die Arbeitspakete (Tasks) des IEA HPT Annex 46 Projekts sind:

Task 1 – Marktübersicht
Task 2 – Systeme und Konzepte
Task 3 – Modellberechnung
Task 4 – Forschung und Entwicklung
Task 5 – Beispielprojekte und Monitoring
Task 6 – Kommunikation

1 – PT Annex 46 - internationales Projekt im Rahmen des IEA Technical Collaboration Program for Heat Pumping Technologies (TCP-HPT) zum Thema Warmwasser-Wärmepumpen (WW-WP).



2 – Entwicklung des Energiebedarfs zur Erzeugung von Brauchwarmwasser und Raumheizung: Die bessere Wärmedämmung reduziert den Bedarf an Raumheizung. Gleichzeitig steigt der Warmwasserbedarf aufgrund höherer Komfortansprüche (Duschen, luxuriöse Bäder, etc.).

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Thank you for your attention

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