Decarbonization and exploring the latest trends of heat pumps shaping sustainable building solutions

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Transition towards sustainable future

MEGATRENDS FUELING STEP-CHANGE IN GROWTH

Climate Change and Sustainability

- EU commitment to cut emissions by 55% by 2030
- ~40% of global carbon emissions come from buildings
- Up to 30% efficiency gains from smart buildings; only 20% of thermostats in Europe are smart / connected

Energy Security

- Targeted reduction in reliance on Russian natural gas
- ~60% of European consumers concerned about financial impact of rising energy costs
- ~70% of EU consumers taking actions to reduce energy consumption at home

Government Regulation and Incentives

- Adding 10M heat pumps in the next five years, facilitated by RePowerEU
- Large-scale climate subsidies across Europe, e.g., €600bn in Fitfor55 EU-program
- 17 European countries have announced or implemented bans on heating systems that use fossil fuel

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Eco-Design & F-Gas

Increase energy efficiency

AND

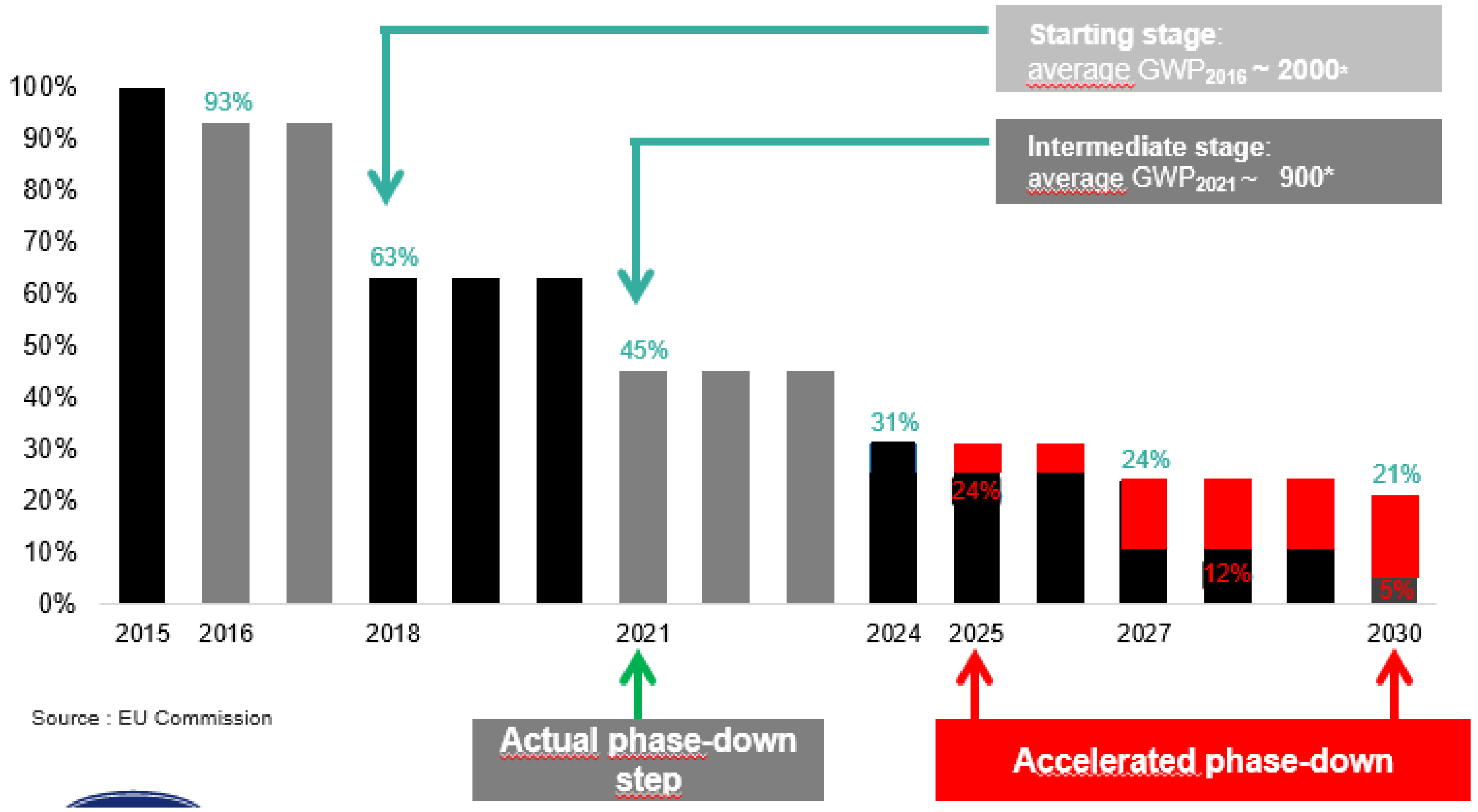
Reduce refrigerant emissions

GWP stands for Global Warming Potential

New version 2024/573

Prevent leak & emission	Reduce use of HFC's
• Leak checks • Recovery • Certification of people	• Phase down • Bans • Traceability

Accelerated Phase-Down Scheme



Updates

- Accelerated phase-down of F-Gas quota in 3 steps between 2025 and 2030 (24%, 12%, 5%).
- EU Commission can allow additional quota in 2025-2029 if HP deployment targets of REPowerEU initiative are threatened
- EU goal is to reach carbon neutrality in 2050.
- GWP Chillers < 750 in 2027
- GWP HP < 150 in 2030 (750 if safety reasons)

⇒ **2030 : Potential risk** on quota / phase out for GWP > 150 (R32, R454B, R513A, R515B)

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			2025	2027	2029	2030	2032	2033	2035	Exception
Chillers	0-12 kW		As today	<150	150	150	Nat	Nat	Nat	Except when required to meet safety standards
	>12 kW		As today	<750	750	750	750	750	750	Except when required to meet safety standards
Heat Pumps & RTU & monobloc package units	0-12 kW		As today	<150	150	150	Nat	Nat	Nat	Except when required to meet safety standards with 750 GWP limit
	>12-50 kW		As today	<150	150	150	150	150	150	Except when required to meet safety standards with 750 GWP limit
	>50 kW		As today	As today	As today	<150	150	150	150	Except when required to meet safety standards with 750 GWP limit
										-
Split air-conditioning and heat pump equipment	Less than 3 kg		<750	750	750	750	750	750	750	No exception
	0-12kW	A2A	As today	As today	<150	150	150	150	Nat	Except when required to meet safety standards
	0-12kW	A2W	As today	<150	150	150	150	150	Nat	Except when required to meet safety standards
	>12kW		As today	As today	<750	750	750	<150	150	Except when required to meet safety standards

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WHAT IS NEXT

On 7 February 2023 the European Chemicals Agency ("ECHA") published a comprehensive dossier concerning a ban on around 10,000 per- and polyfluoroalkyl substances ("**PFAS**").
The restriction proposal aims to restrict the manufacture, placing on the market and use of substances harmful to human health and the environment, and to limit their associated risks. The ban is to be implemented under Regulation (EU) No 1907/2006 ("REACH").
An initial open consultation has been completed, and ECHA's scientific committees are now examining the potential impacts of the restriction proposal.

- **PFAS** are widely used, long lasting chemicals, components of which break down very slowly over time.
- Because of their widespread use and their persistence in the environment, many **PFAS** are found in the blood of people and animals all over the world and are present at low levels in a variety of food products and in the environment.
- **PFAS** are found in water, air, fish, and soil at locations across the nation and the globe.
- Scientific studies have shown that exposure to some **PFAS** in the environment may be linked to harmful health effects in humans and animals.
- There are thousands of **PFAS** chemicals, and they are found in many different consumer, commercial, and industrial products. This makes it challenging to study and assess the potential human health and environmental risks.

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Trifluoroacetic acid (**TFA**) meets the definition of **PFAS** because it has a -CF3 (methyl) radical on the molecule.

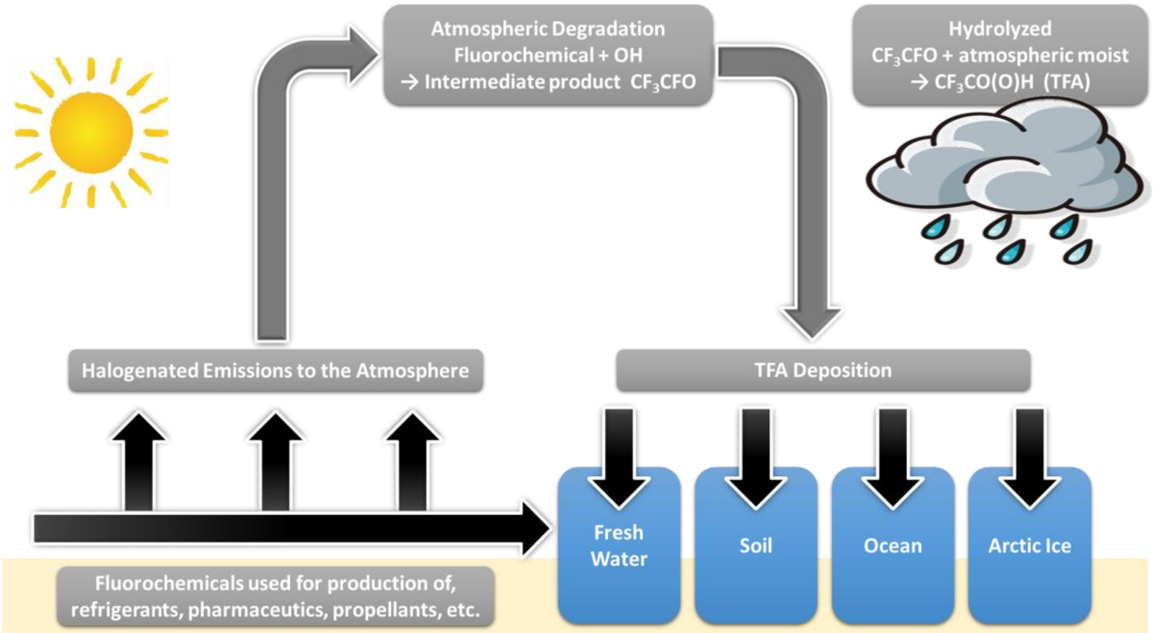
In order to reduce direct emissions of refrigerants new chemical low-GWP refrigerants were introduced to the market and advertised as a promising solution.

Already the previous HFC refrigerants (e.g. R134a) were found to yield **trifluoroacetic acid** (**TFA**) as a degradation product when released to the atmosphere (Wallington et al., 1996) causing concerns for **environmental safety**.

Some of the newly introduced low-GWP refrigerants have higher yields of TFA (WMO, 2011) and therefore have a higher potential of polluting the **environment**.

Refrigerant	Formula / Composition (%)	GWP	TFA yield
R134a	-	3,900	10 – 20 %
R1234yf	-	4	100 %
R1234ze(E)	-	7	< 10 %
R513A	R1234yf/134a (56/44)	573	~ 62%
R515B	R1234ze/R227ea (91.1/8.9)	293	< 18%
R454B	R32/1234yf (68.9/31.1)	466	~ 31%
R32	-	675	0%
R454C	R32/R1234yf (21,5/78,5)	148	??

***Trifluoroacetic** acid (**TFA**; CF3CO(O)H) is a short-chain per-fluorinated carbolic acid (scPFCA, CnF2n+1CO2H with n≤3), that has a high solubility in water, is very persistent in the **environment** and considered to be very mobile (Solomon et al., 2016).



**Trifluoroacetic acid (TFA), acts on hepatocyte proteins to produce trifluoroacetylated components.

A severe type of liver injury is associated with an acute increase of liver enzymes, alanine aminotransferase (ALT) and aspartate aminotransferase (AST), which remain elevated for one to two weeks following exposure and resolve without treatment (Wright et al., 1975).

Similar to the ALT concentrations measured in the study used by Umwelt Bundesamt (2020).

*Source: IIF-IIR, Morlet, V., Coulomb, D., & Dupont, J. L. (2017), Global Ozone Research and Monitoring Project–Report No. 52
**Source: Revolution Industriekälte GmbH, Thomas Frank, 22.02.2021, WMO: World Meteorological Organization

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WHAT IS NEXT
Regulation (EU) No 1907/2006 (“REACH”)

PFAS definition

EU will most probably adopt the OECD’s definition which will impact the existing refrigerants such as below

Single Component Refrigerants Non-Concerned

Refrigerant	Formula
R-32	CH2F2
R-152	CH2FCH2F
R-152a	CH3CHF2
R-1132(E)	CHF=CHF
R-1270 (propene)	C3H6
R-290 (propane)	C3H8
R-744	CO2
R-717 (ammonia)	NH3
R-728 (nitrogen)	N2

Single Component Refrigerants Possibly Ban

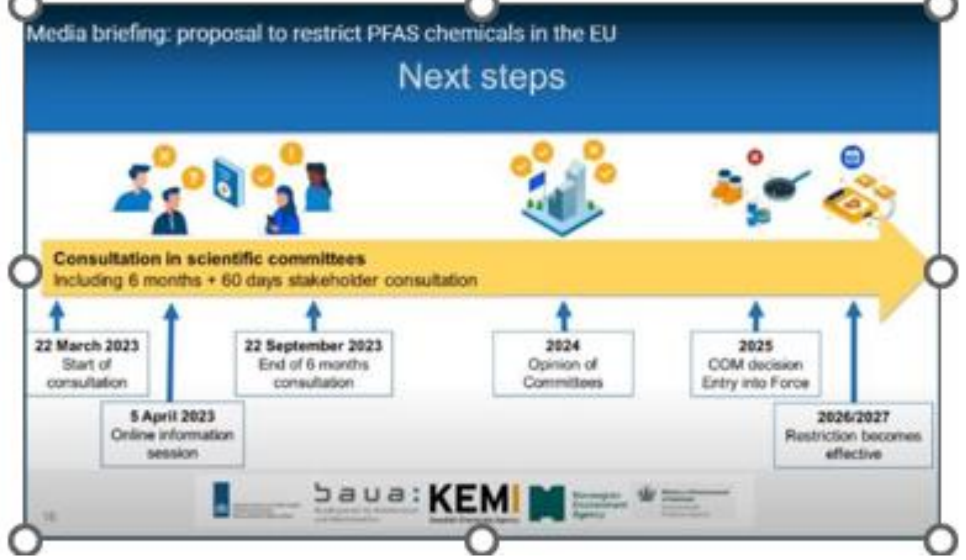
Refrigerant	Formula
R-134a	CH2FCF3
R-1234yf	CF3CF=CH2
R-1234ze(E)	CF3CH=CFH
R-1233zd(E)	CF3CH=CHCl

Blended Refrigerants Possibly Ban

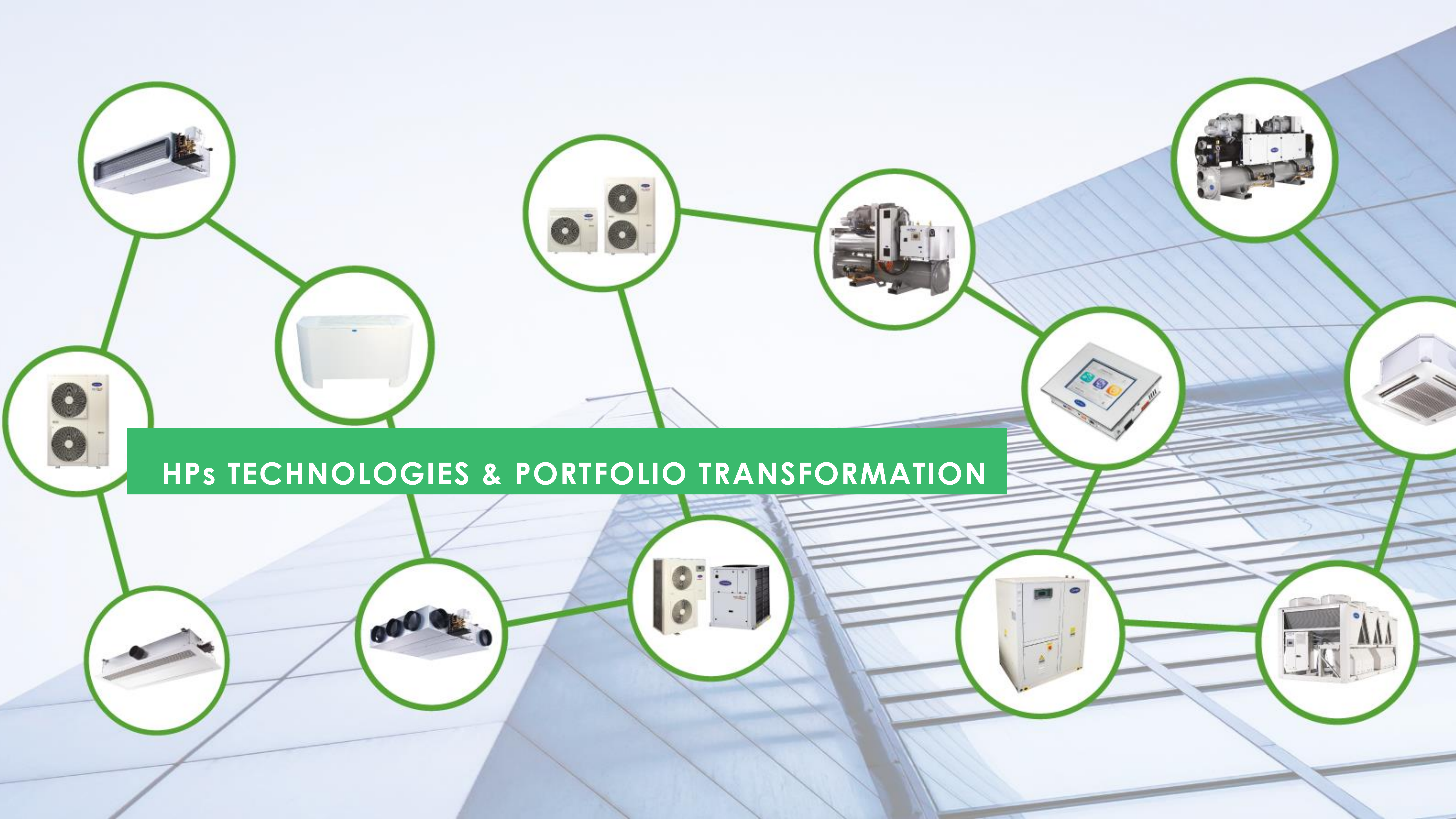
Refrigerant	Components	Formula
R-410A	R-32	CH2F2
	R-125	CHF2-CF3
R-404A	R-125	CHF2-CF3
	R-143a	CH3CF3
	R-134a	CH2FCF3
R452A	R-32	CH2F2
	R-125	CHF2-CF3
	R-1234yf	CF3CF=CH2
R-454A/B/C	R-32	CH2F2
	R-1234yf	CF3CF=CH2
R-513A	R-1234yf	CF3CF=CH2
	R-134a	CH2FCF3
R-515B	R-1234ze(E)	CF3CH=CFH
	R-227ea	CF3CHFCF3

Time line

Estimated: Mid-2027 effective



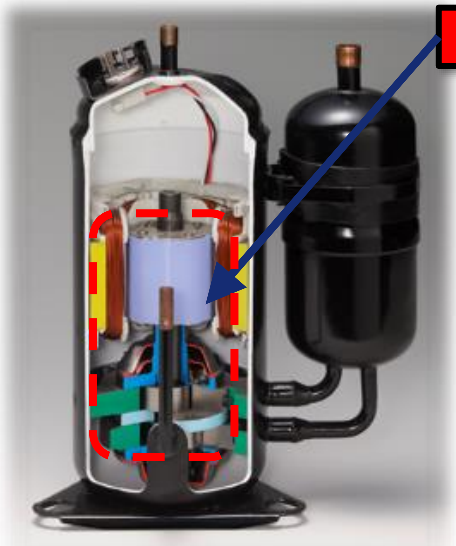
The OECD (Organisation for Economic Co-operation and Development) is a forum and knowledge hub for data, analysis and best practices in public policy. We work with over 100 countries across the world to build stronger, fairer and cleaner societies - helping to shape better policies for better lives.

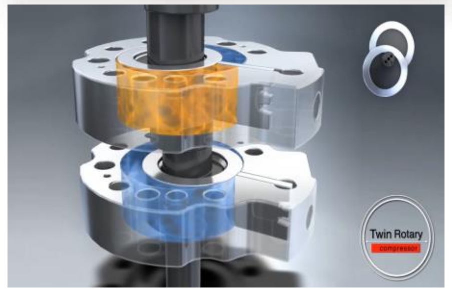

HPs TECHNOLOGIES & PORTFOLIO TRANSFORMATION

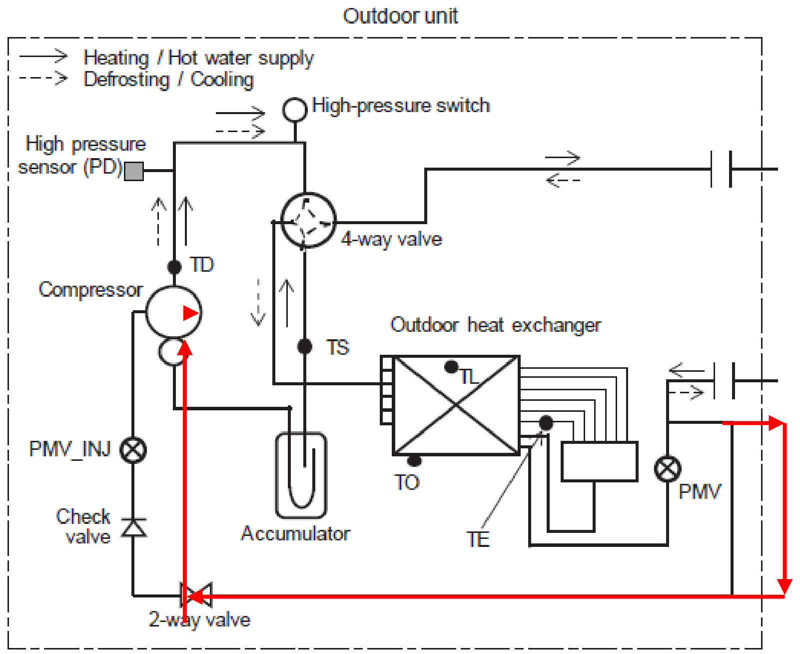
HP Technologies (Residential)

Twin Rotary DC Compressor with Liquid Injection

Liquid Injection







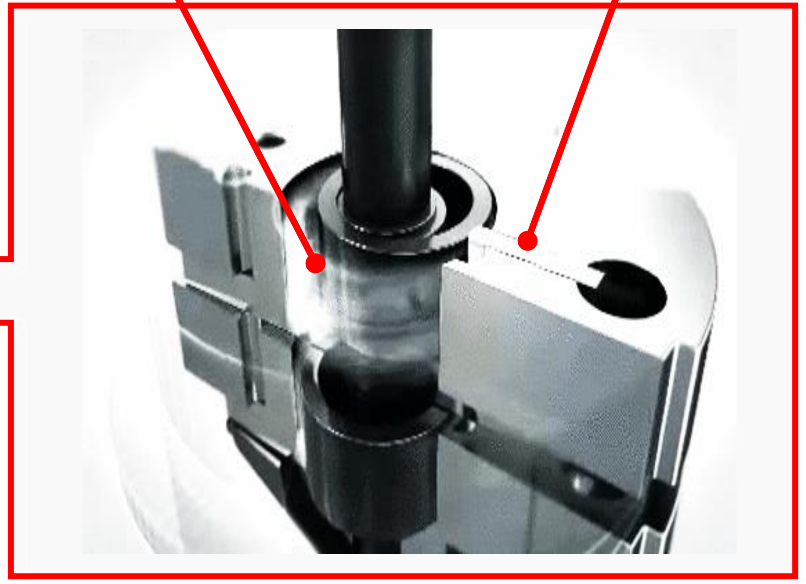
- **High precision Controller for Frequency of compressor for absolute control .**

Broader Operation Map for Lower Air temperatures

Twin Rotary DC Compressor with Diamond Like Carbon (DLC)

Durable Cylinder

DLC treated piston

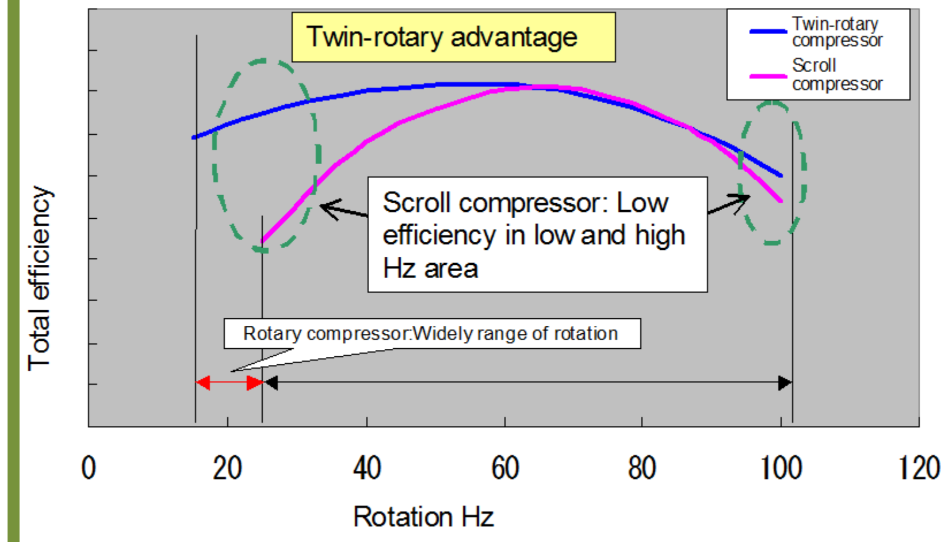


Efficient and withstand in time.

HP Technologies (Commercial)

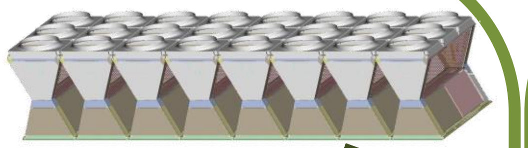
Tech.1

Compressor 100cc Twin Rotary

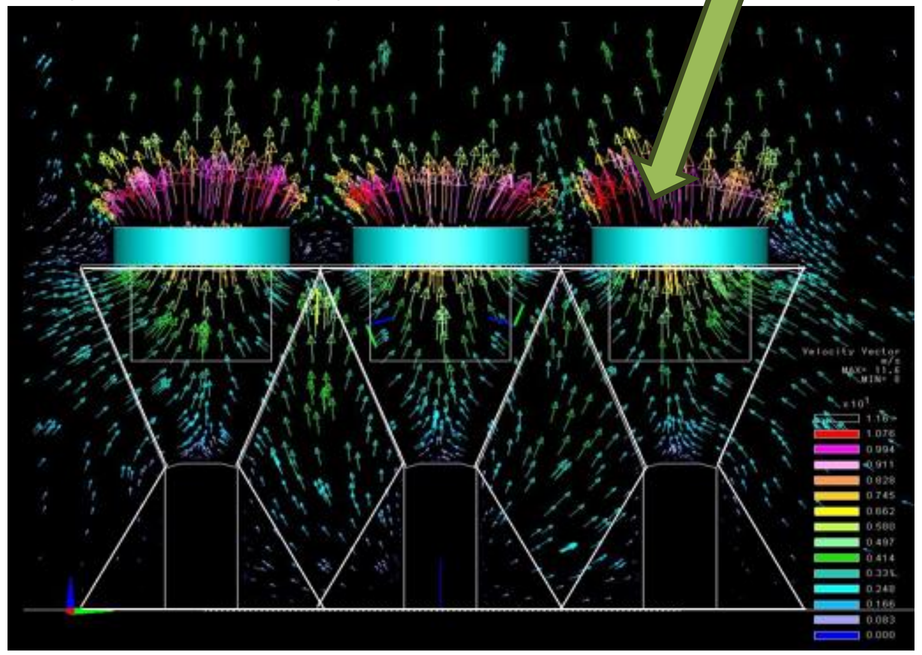


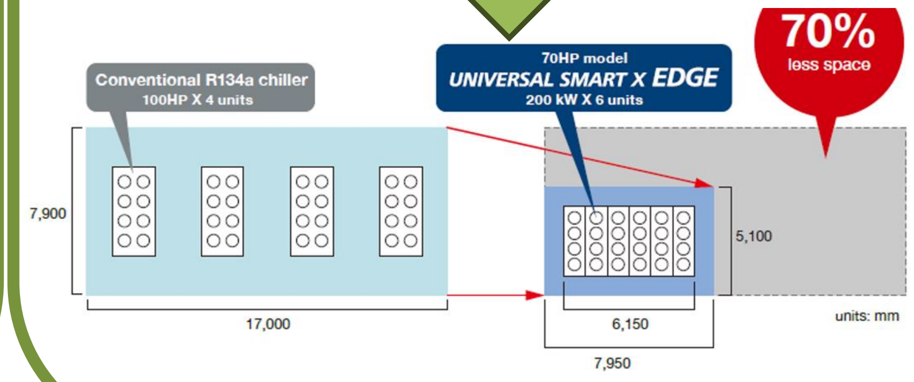
Very Efficient in Part Loads
& Broader Operation Map
for Lower Air temperatures

Tech.2



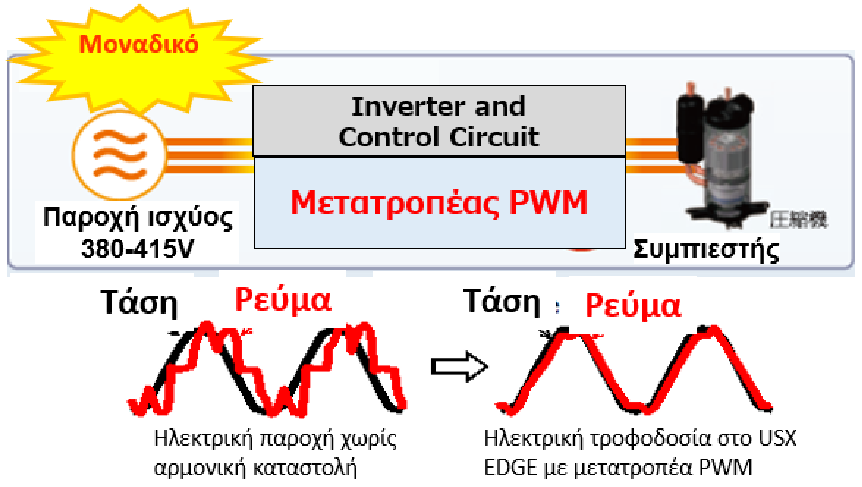
Unique Patented X-shaped Design
With CFD (Computational fluid
dynamics) analysis





Tech.3

PWM converter of USX EDGE with
almost no electrical Distortions

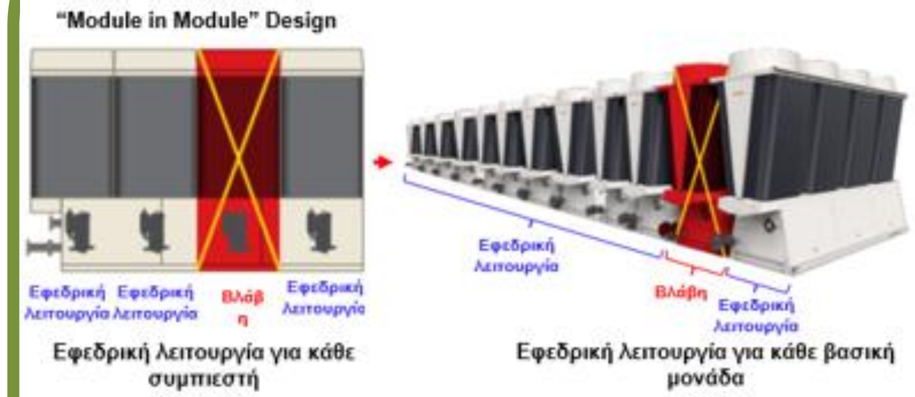


Low Harmonics
+
Unique Power Factor of **99%**

No need for additional expenses
with local electrical filters

Tech.4

Modular Design

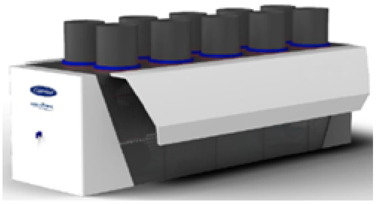


Maximum Diversity.

4 independent cooling circuits / module.

Additional efficiency and minimizing power losses

Portfolio Transformation

	 MODULAR			 UNIQUE PRODUCT, MODULAR	
High-temperature air - cooled heat-pump	High-temperature air - cooled heat-pump	Mid-temperature air - cooled heat-pump	Mid-temperature air - cooled heat-pump	Mid-temperature MODULAR air - cooled heat-pump	High-temperature air - cooled heat-pump
R290	R290	R32	R32	R32	HFO R1234yf
75°C	70°C	60°C	55°C	55°C	82°C
4kW – 16kW	20kW – 160kW	40kW – 160kW	170kW – 940kW	150kW – 25,6MW	410kW
SPACE HEATING	SPACE HEATING	SPACE HEATING	SPACE HEATING	SPACE HEATING	INDUSTRIAL PROCESS
HOT WATER PRODUCTION	HOT WATER PRODUCTION	+ HR OPTION HOT WATER PRODUCTION	+ HR OPTION HOT WATER PRODUCTION (80°C)		HOT WATER PRODUCTION

Portfolio Transformation

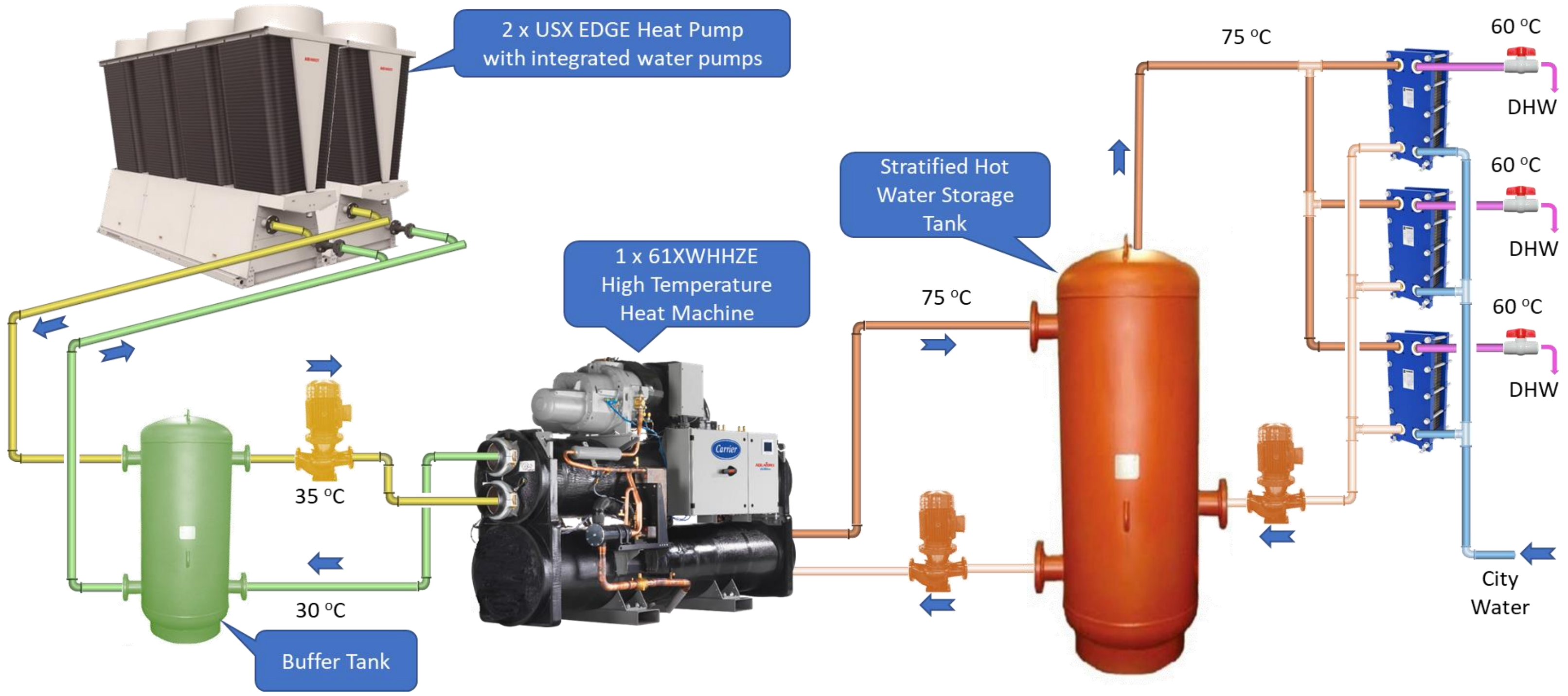
					
Mid-temperature water - cooled heat-pump	Mid-temperature water - cooled heat-pump	Mid/High-temperature water - cooled heat-pump	High-temperature water - cooled heat-pump	Very-High-temperature water- cooled heat-pump	Ultra-High-temperature water - cooled heat-pump
R410	R410	HFO R1234ze / R515B	HFO R1234ze	HFO R1234ze	HFO R1233ze
60°C	65°C	up to 70°C	85°C	92°C	120°C
29kW – 230kW	29kW – 230kW	317kW – 1.919kW	200kW – 2.500kW	415kW – 750kW	110kW – 540kW
SPACE HEATING	SPACE HEATING	SPACE HEATING	DISTRICT HEATING	DISTRICT HEATING	DISTRICT HEATING
	HOT WATER PRODUCTION	HOT WATER PRODUCTION	SPACE HEATING	INDUSTRIAL PROCESS	INDUSTRIAL PROCESS
		INDUSTRIAL PROCESS	INDUSTRIAL PROCESS		
			HOT WATER PRODUCTION		

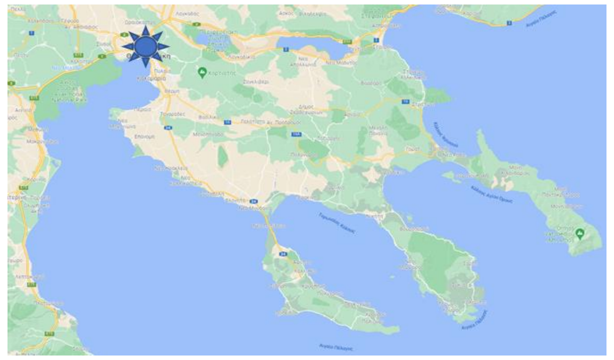
Case Studies

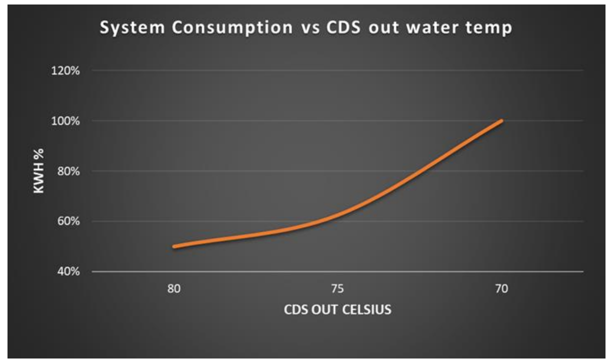
Decarbonization, Expanding the Concept

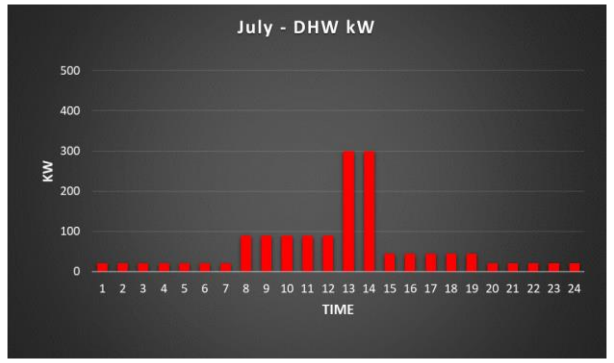
Decarbonization – Hot Water

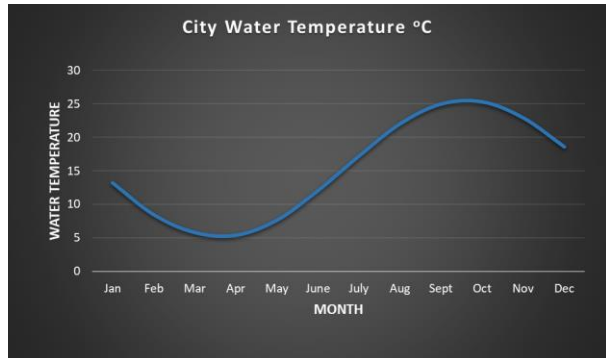
City:	Thessaloniki - Greece
Type:	Hospital
Size:	210 beds
Total DHW:	35 m^3 per day @ 60 °C (Engineering Toolbox data)
Weather file:	ASHRAE IWEC2
DWH profile:	ASHRAE(daily), ADEME guide technique (annually)
Tap water temp. profile:	Buried @ 1.3 m (8760 hours simulation)
Simulation analysis:	8760 hours (in house SW / Charging Storage Tank)
A/C and W/C HP data:	Manufacturer selection and part load data
Oil / Gas Boiler data:	COMNET Manual (Building Descriptions Reference)

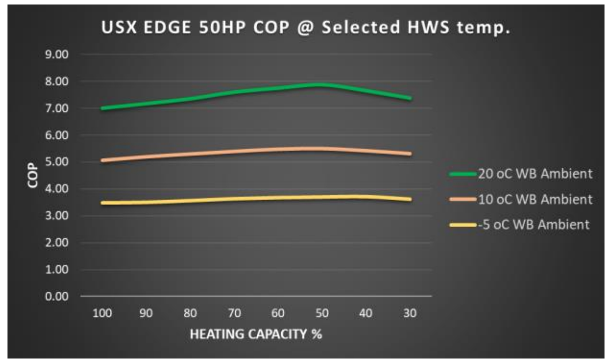


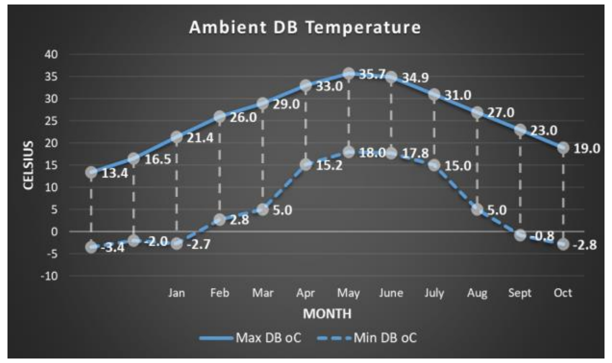


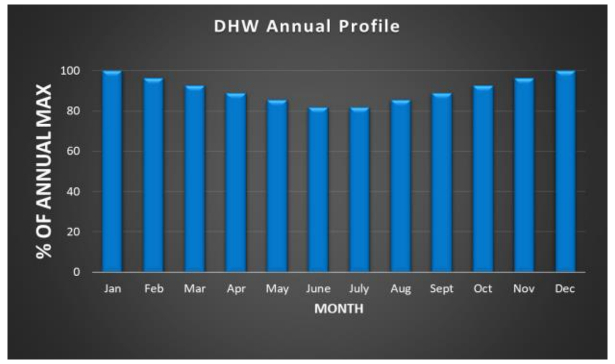


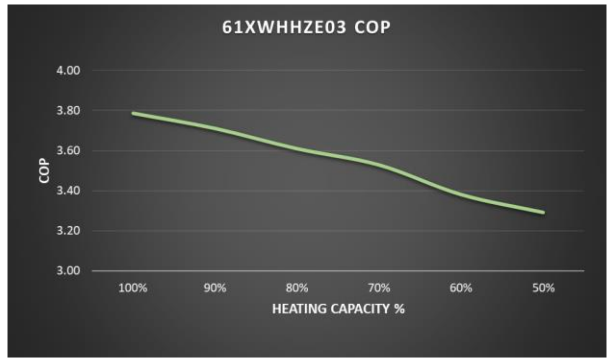












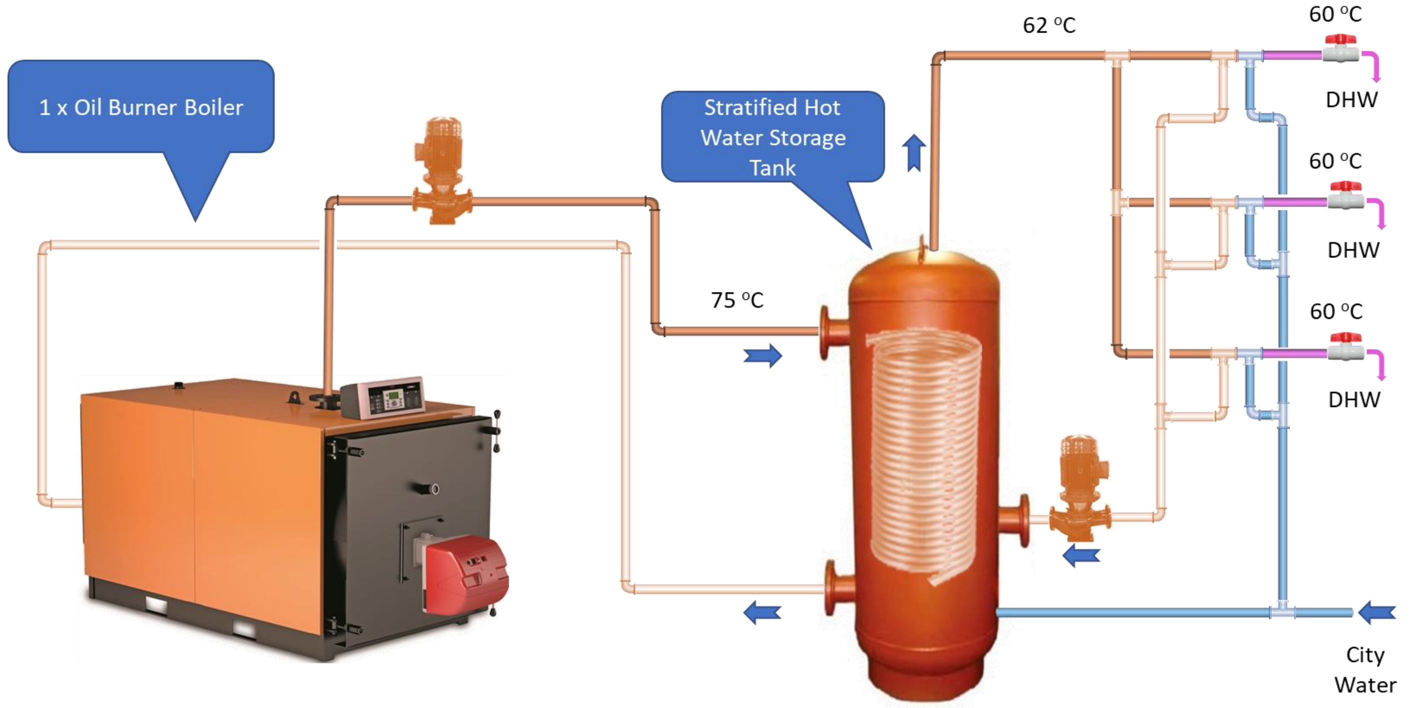
$$Fuel_{partload} = Fuel_{design} \times FHeatPLC(Q_{partload}, Q_{rated})$$

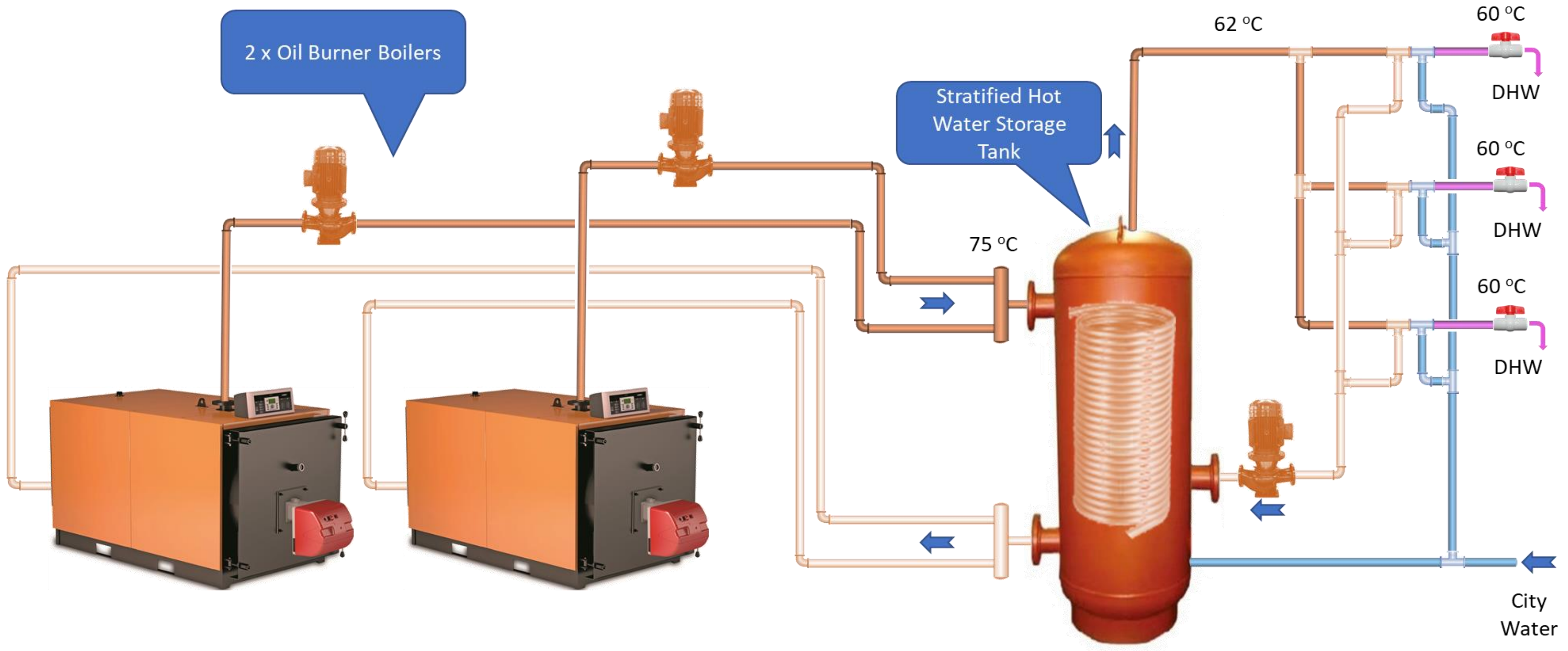
$$FHeatPLC = \left(a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left(\frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

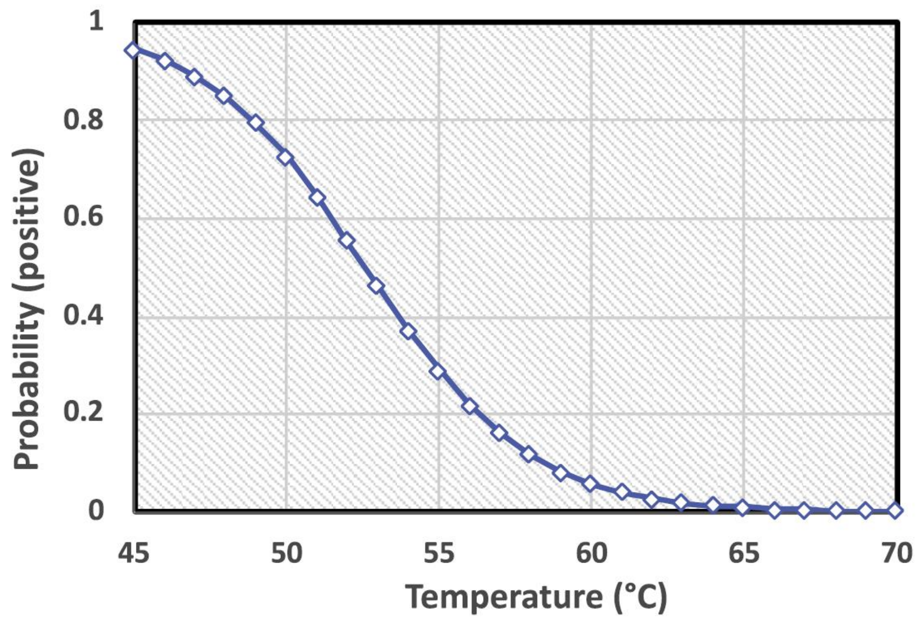
where

FHeatPLC	The Fuel Heating Part Load Efficiency Curve
$Fuel_{partload}$	The fuel consumption at part load conditions (Btu/h)
$Fuel_{design}$	The fuel consumption at design conditions (Btu/h)
$Q_{partload}$	The boiler capacity at part load conditions (Btu/h)
Q_{rated}	The boiler capacity at design conditions (Btu/h)
a	Constant, 0.082597
b	Constant, 0.996764
c	Constant, -0.079361

Decarbonization – Hot Water







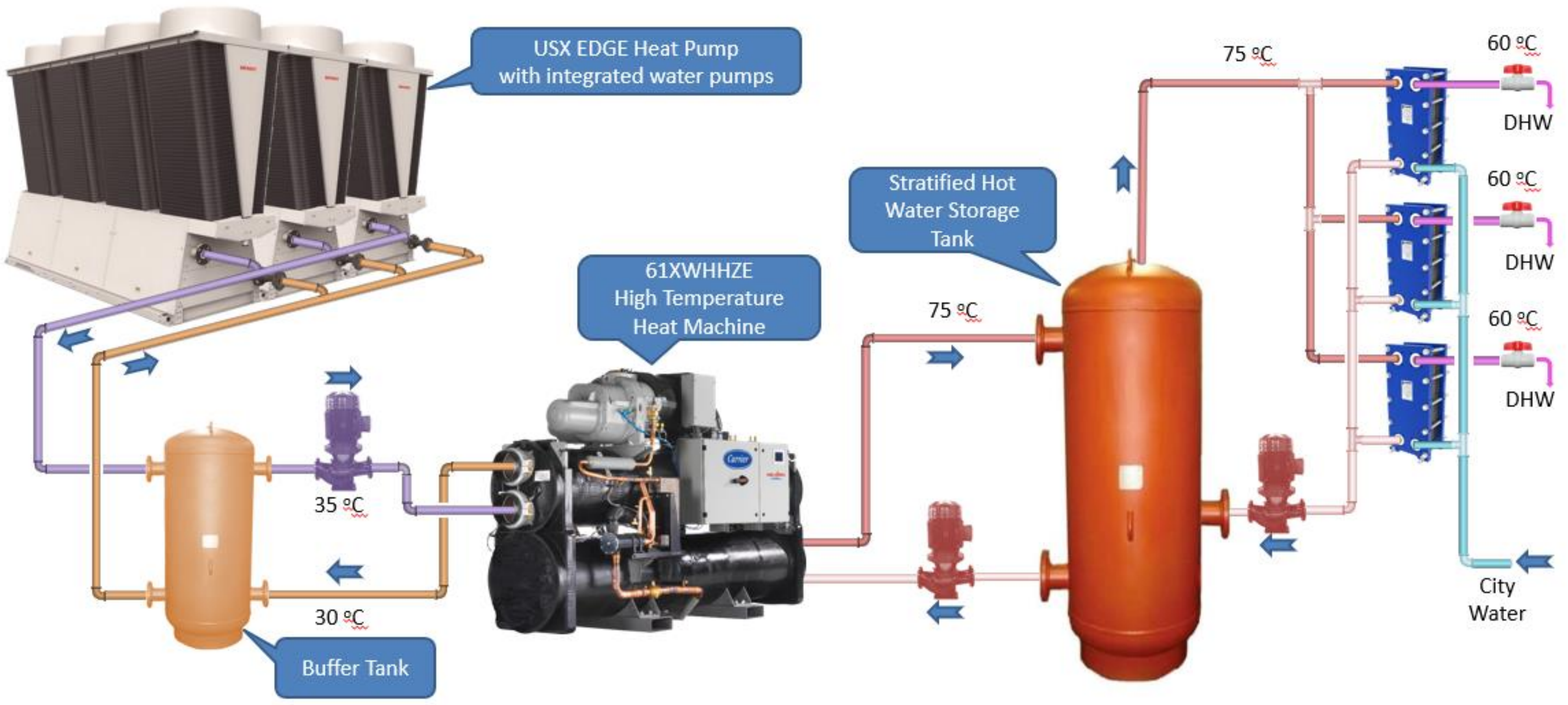
Probability of Legionella positive events at different hot water tap temperatures
Md Rasheduzzaman, Rajveer Singh, Charles N. Haas, Patrick L. Gurian
Department of Civil, Architectural and Environmental Engineering, Drexel University, Philadelphia, USA

Key findings

- Scale reduces energy efficiency of the water heater by up to 50%
- Water temperature decreases 5°C with a limescale thickness of 2mm
- The water heater‘s useful life can be reduced by as much as 50% through scale build-up
- 0.5 mm of hard scale increases fuel costs by 9.4%

- References
- i) Battelle Memorial Institute, Columbus, OH, Study on Benefits of Removing Hardness (calcium & magnesium ions) from a water supply, 2009
- ii) Influence of Limescale on Heating Elements Efficiency http://www.comsol.it/conference2013/europe/abstract/id/15419/pezzin_abstract.pdf
- iii) Ministry of Health UK, Report of the Subcommittee of the Central Advisory Water Committee, 1949 iv) The Office of Saline Water, U S Department of the Interior

Decarbonization – Hot Water



Advantages

Closed loop hot water system
Lower cost of storage tank (no internal HE)
Easy scale and legionella control
Longer life of Storage Tanks

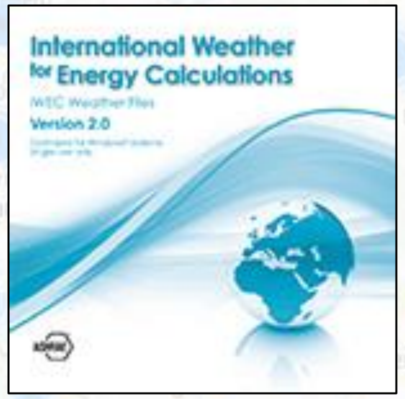
Disadvantages

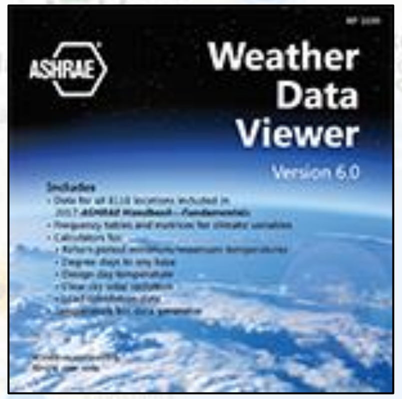
Remote PHE first cost
Remote PHE maintenance
Recirculation Pump higher head

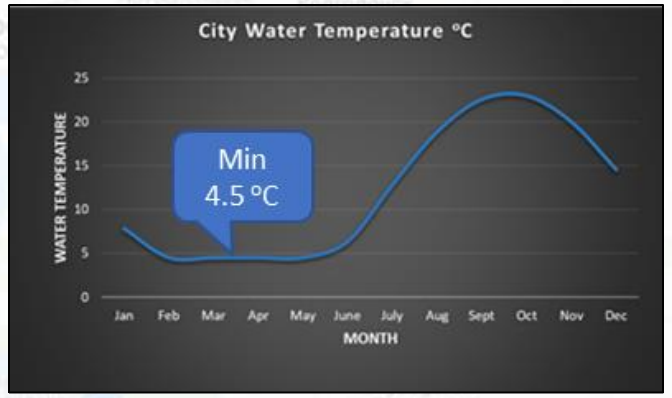
Decarbonization – Hot Water

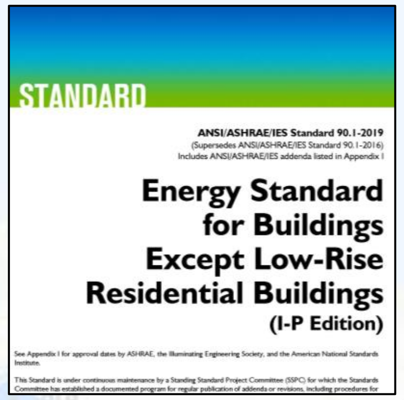
Build in Algorithms

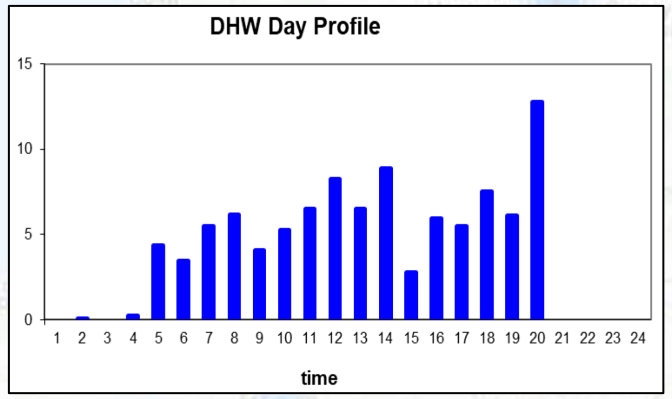
- Weather Data
- City water temperature
- DHW daily Profile
- DHW annual profile
- A/C heat pumps data points
- 61XWH data points
- Burner data points
- Storage tank
- Buffer tank
- Distribution water pumps
- A/C heat pumps water pumps
- 61XWH water pumps
- Storage control algorithm
- A/C heat pumps sequencing
- 61XWH sequencing

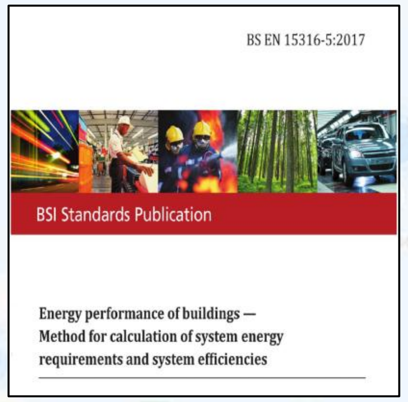


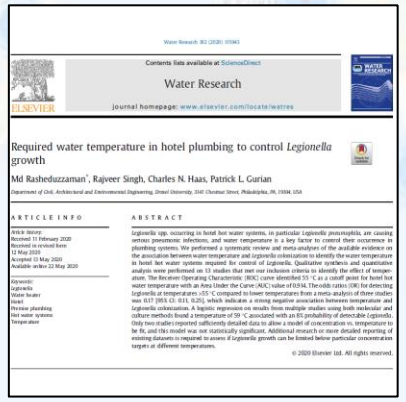


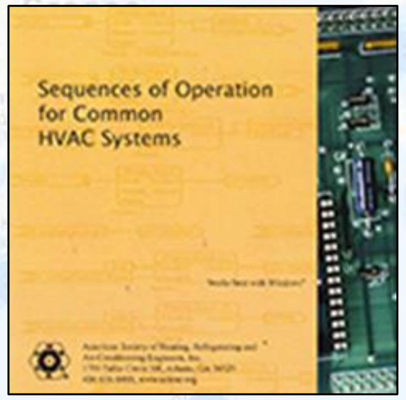


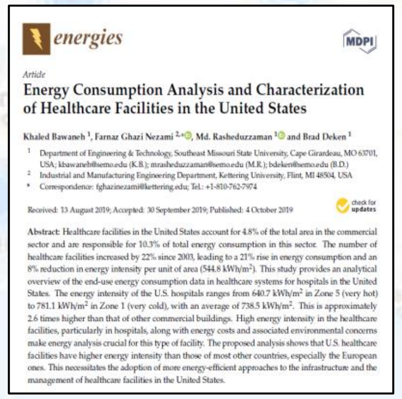


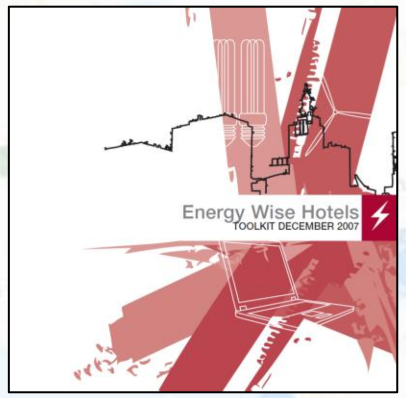


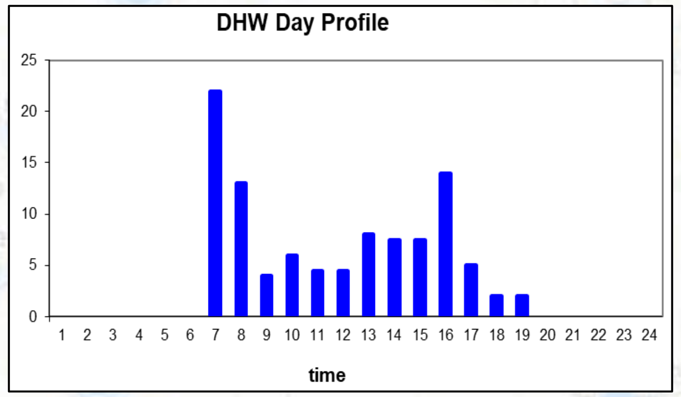












Decarbonization – Hot Water

General Data

City Name	GR_THESSALONIKI(AP)
Profile	Hospital_new Monthly factors
DHW Max Consumption m^3 per Day @ 60 °C	35.00

Building type	Hospital
Heat Pump capacity kW	**428**
Heat Pump min HWST °C	**75**
Heat Pump max daily operating hours (in average)	4.2
Daily max DWH volume lt	35,000
Daily max DWH power kW	409
Daily max DWH energy kWh (in average)	2,044
Storage tanks arrangement	Stratified Storage Tank Custom Made
Storage capacity factor "X"	0.6
Storage stratification efficiency %	98
Storage recovery time (in average) hours	0.57
DHW temperature set point °C	60
Storage temperature set point °C	75
Storage temperature dead band °C	13
PHE approach (Storage - DHW) °C	2
PHE approach (Heat Pump - Storage) °C	0
61XWH starts @ 63 oC and ends @ 75oC Storage water temp.	12
Proposed 1 total storage volume lt	21,500
Proposed 2 total storage volume lt	0
Selected total storage volume lt	16,000
61XWH min requested load %	52.32
Buffer Tank with baffles Volume (USX EDGE 60HP side) lt	7,400

Volume for 5 minutes operation of 61XWH and 4 oC water DT

Warning	

Storage and Buffer Tanks

Heat Pump is Loading Storage tank

Water to Water Heat Pump	
Type	61XWHHZE03
CDS Supply Water Temperature °C	75
EVP Supply Water Temperature °C	30
61XWHHZE03 min unload %	50
EVP Variable Water Flow	
CDS Variable Water Flow	
Ext Piping CW ΔP kPa (Var Flow)	45
Ext Piping HW ΔP kPa (Cnst Flow)	40
Secondary CW Piping Dsgn ΔT °C	5
Secondary HW Piping Dsgn ΔT °C	5
Water Pump total eff. %	0.7

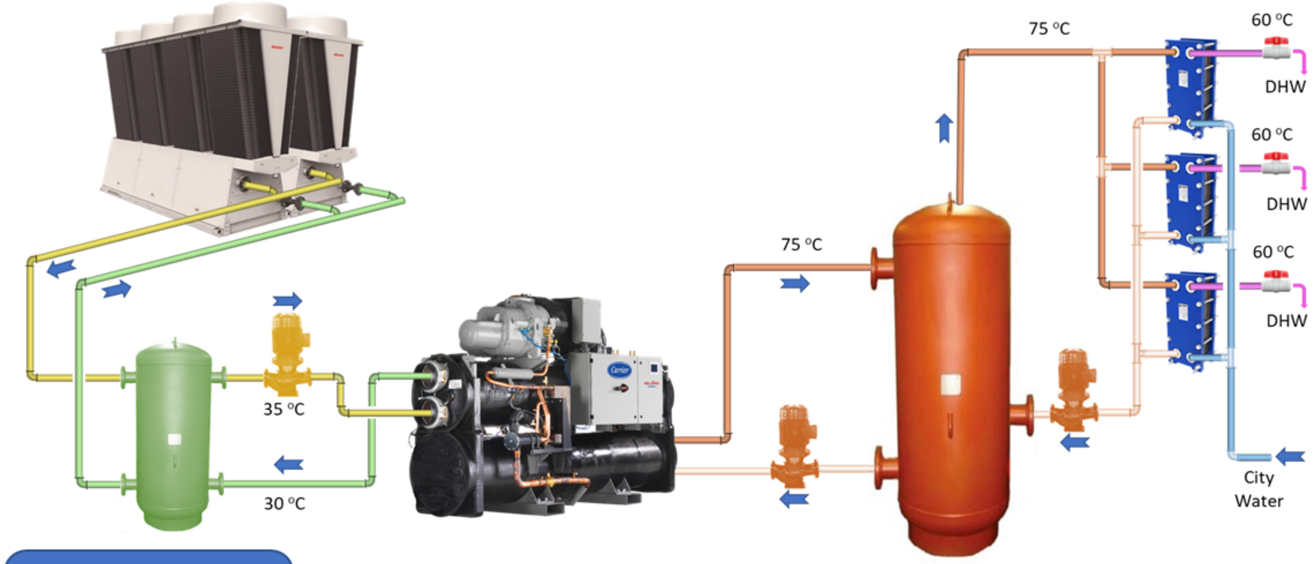
Water Cooled Heat Pump

Air Cooled Heat Pump	
Type	USX EDGE 60HP — STD
USX EDGE 60HP min unload %	25
Ext Pipe Dsgn ΔP kPa (Var Flow)	5
Secondary Piping Design ΔT °C	5
Water Pump total eff. %	0.7

Air Cooled Heat Pump

Burner Boiler	
Type	Diesel
Propozed Boiler Size kW	400
Boiler Size kW	400
Burner min unload %	60
Water Pump total eff. %	0.7

Boiler / Burner



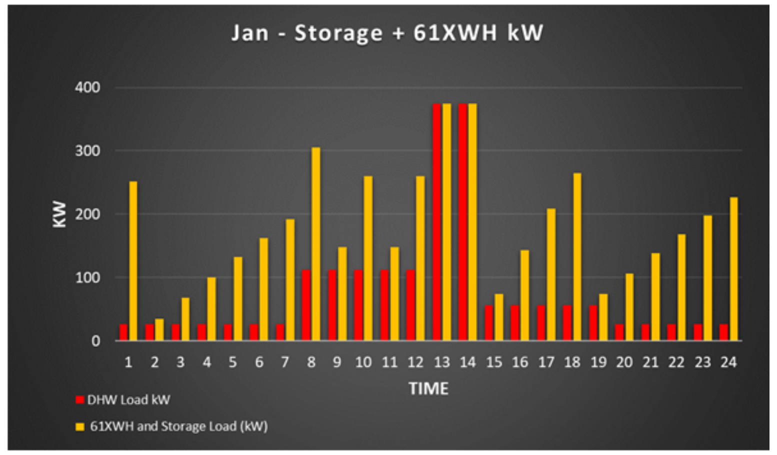
Decarbonization – Hot Water

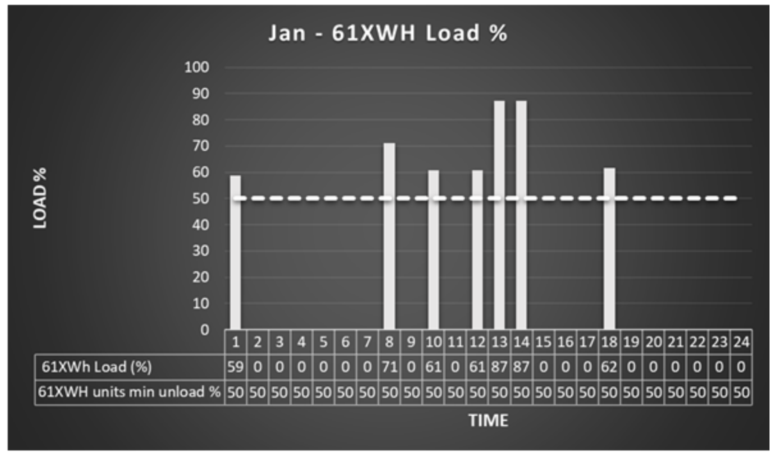
Running Cost Heat Pumps

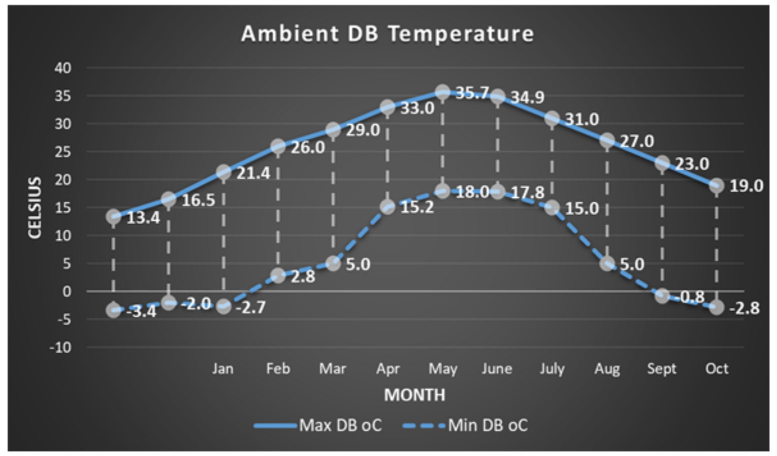
Month	Operation	Heating Load kWh	61XWH System Total kWh_{el}	A/C HP System Total kWh_{el}	SCOP (Includes Water Pumps)	Heat Pump System Total Cost €
Jan	Yes	64,749	19,103	16,187	1.83	3,882
Feb	Yes	61,446	17,942	14,953	1.87	3,618
Mar	Yes	68,635	20,001	16,383	1.89	4,002
Apr	Yes	64,267	18,883	13,127	2.01	3,521
May	Yes	61,294	18,314	10,855	2.10	3,209
June	Yes	52,647	15,623	8,454	2.19	2,648
July	Yes	48,104	14,214	7,741	2.19	2,415
Aug	Yes	47,239	13,961	7,718	2.18	2,385
Sep	Yes	43,535	12,926	7,621	2.12	2,260
Oct	Yes	45,856	13,531	9,005	2.03	2,479
Nov	Yes	49,354	14,781	9,814	2.01	2,706
Dec	Yes	56,179	16,685	12,980	1.89	3,263
Total		663,305	195,965	134,837	2.01	**36,388**

Running Cost Boiler / Burner

Boiler System Total kWh_{el}	Burner Fuel Type	Diesel Energy kWh	Diesel Consumption kg	Boiler System Total Cost €
73	Diesel Heating	79,662	6,700	8,484
69	Diesel Heating	74,944	6,303	7,981
77	Diesel Heating	83,548	7,027	8,898
73	Diesel Heating	78,790	6,627	8,391
71	Diesel auto	76,153	6,405	12,200
60	Diesel auto	65,163	5,480	10,439
54	Diesel auto	58,669	4,934	9,399
53	Diesel auto	57,615	4,846	9,230
50	Diesel auto	53,565	4,505	8,581
51	Diesel Heating	55,605	4,677	5,922
57	Diesel Heating	61,422	5,166	6,541
64	Diesel Heating	69,269	5,826	7,377
752		814,404	68,495	**103,444**







Number of Units

61XWHHZE03 Annual Operating Hours:	2,232
Selected # of Units 61XWHHZE03 is:	1
Selected # of Units USX EDGE 60HP is:	2
Selected # of Boiler Diesel is:	1
A/C HP Possible Load Unmet Hours	0
Burner Boiler Possible Load Unmet Hours	0

Weather Data

Heating Weather File	
99.6% DB °C	-3.0
MIN DB °C	-3.4
MCWB WB °C	-4.0
Cooling Weather File	
0.4% DB °C	34.8
MCWB °C	21.7
MAX DB °C	35.7
MCWB WB °C	18.1

Fuel Cost

Fuel Type	Market Cost	Unit
Electricity	0.11	€/kWh
Diesel Heating	1.05	€/lt
Diesel Auto	1.58	€/lt
Natural Gas	0.50	€/m^3
Butane	1.40	€/kg
Propane	1.52	€/kg
Wood	15.00	€/m^3

Questions

&

Answers

Contact us if there are any questions.

Thank you for your time!

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