The ‘science bit’ - how heat pumps work and why they are so efficient

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DARTMOOR ENERGY
Renewable Energy & Retrofit Specialists

- Renewable Energy & Retrofit Specialists
- Founded in 2018
- 11 Team Members
- We work with…
  - Local Energy Communities (surveys, designs, coordination's, consultancy, grants)
  - Local Councils (surveys, designs, consultancy, grants)
  - Energy Companies (surveys)
  - Select Trusted Installers (surveys, designs, coordination, customer management, quoting)
  - Homeowners (reports, consultancy works, quoting)

Are heat pumps a new technology?

Types of heat pumps…

Numbers…

- 1834 – First vapour compression refrigeration system.
- 1945 – First domestic heat pump for heating in the UK .
- 1 million heat pumps installed in the UK for domestic heating.
- 190 million heat pumps installed worldwide for domestic heating and cooling.

Heat pumps are not a new technology

How do heat pumps work?

The science bit…

Refrigerants

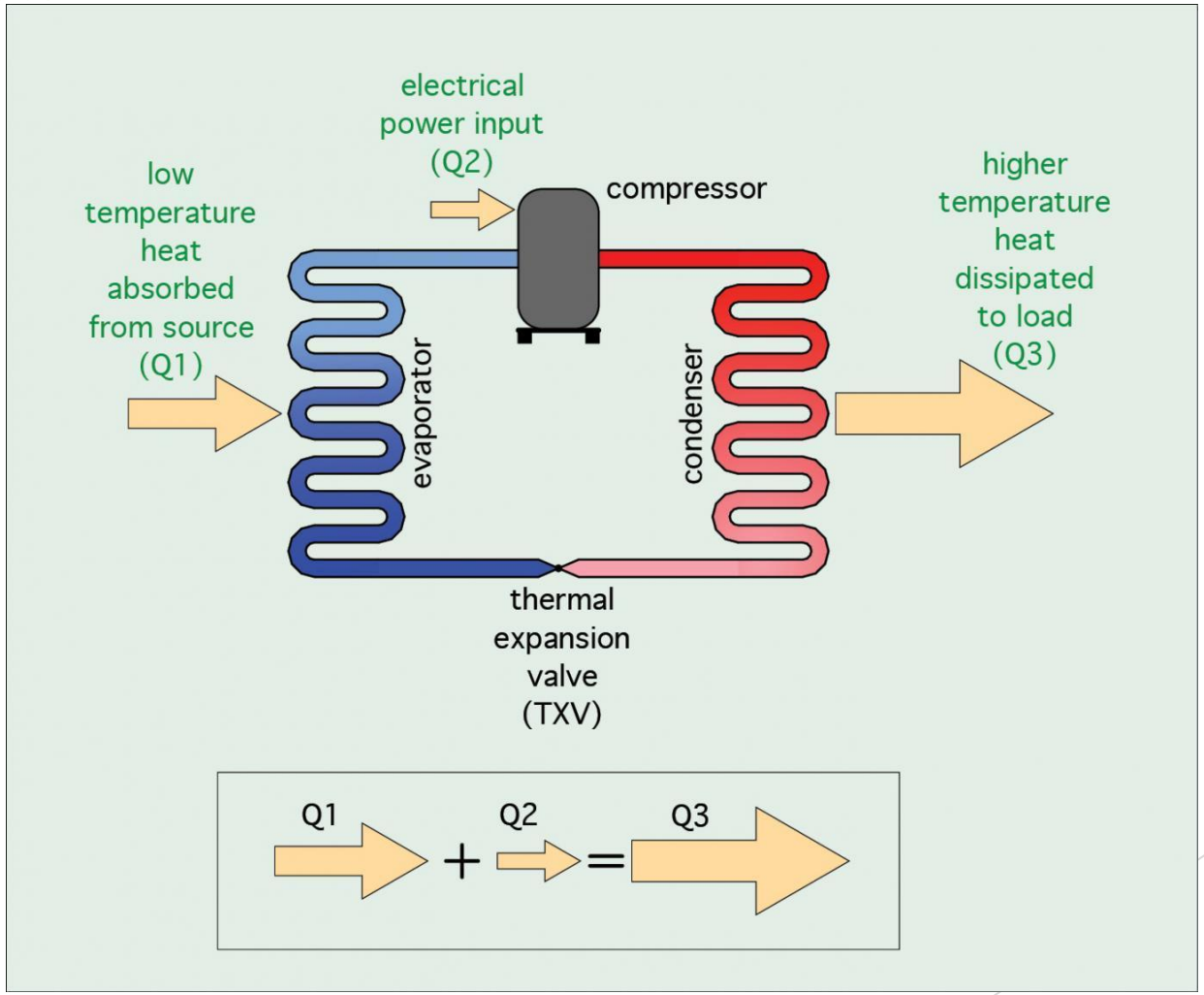
	Boiling (evaporation) Temperature	Global Warming Potential (GWP)
Water	100C	0
R410A	-52C	2,088
R32	-51C	675
R290	-42C	3

	Global Warming Potential (GWP)
Carbon Dioxide	1
Methane	28-36
Hydroflurocarbon (used in refrigerators and car ACs)	1,430

The science bit…

Refrigeration Cycle

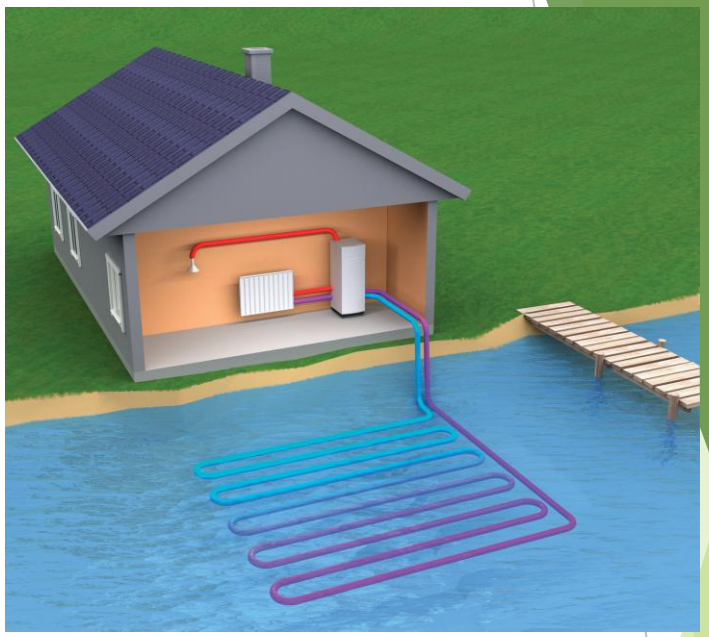
High Temperature / High Pressure

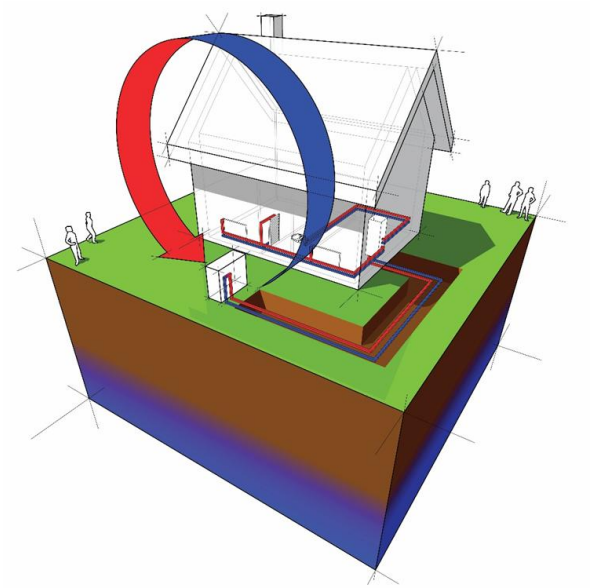


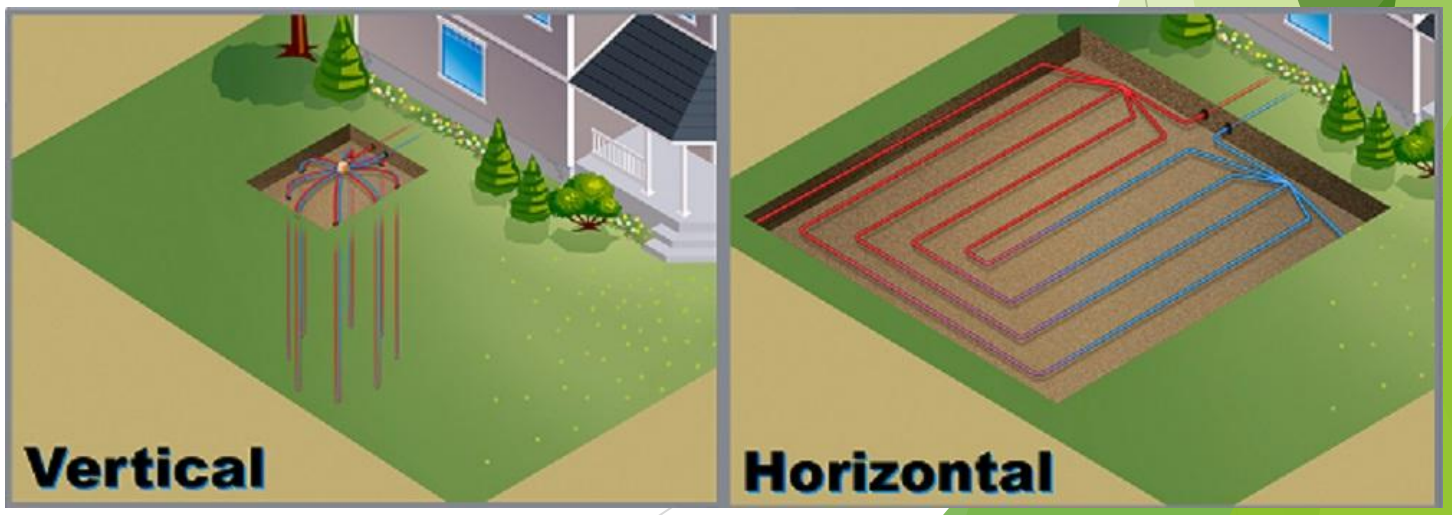
Low Temperature / Low Pressure

The science bit…

Types of domestic heat pumps







What size heat pump do I need?

The science bit…

Heat Loss Calculations

Process…

- Confirm the outdoor design temperature.
- Determine thermal values of all elements of the property (u-values).
- Measure every floor, wall, roof, window and door – every room!
- Estimate/measure the air permeability level.

Property Heat Loss = X	Heat Pump Sizing = X + 10-20%

The science bit…

Heat Loss Calculations

The science bit…

Heat Loss Calculations

- Determine thermal values of all elements of the property (u-values).

External Wall 1			
Material	Thickness	Thermal conductivity (k)	R Value (m2 K /W)
Internal surface (horizontal heat flow	0	0.000	0.130
Gypsum (plaster)	3	0.350	0.009
-	0	0.000	0.000
-	0	0.000	0.000
-	0	0.000	0.000
Stone (Granite)	600	1.730	0.347
External surface (horizontal heat flow	0	0.000	0.040
-	0	0.000	0.000
-	0	0.000	0.000
-	0	0.000	0.000
-	0	0.000	0.000
Total R Value			**0.525**
U Value (W / m2 K)			**1.903**

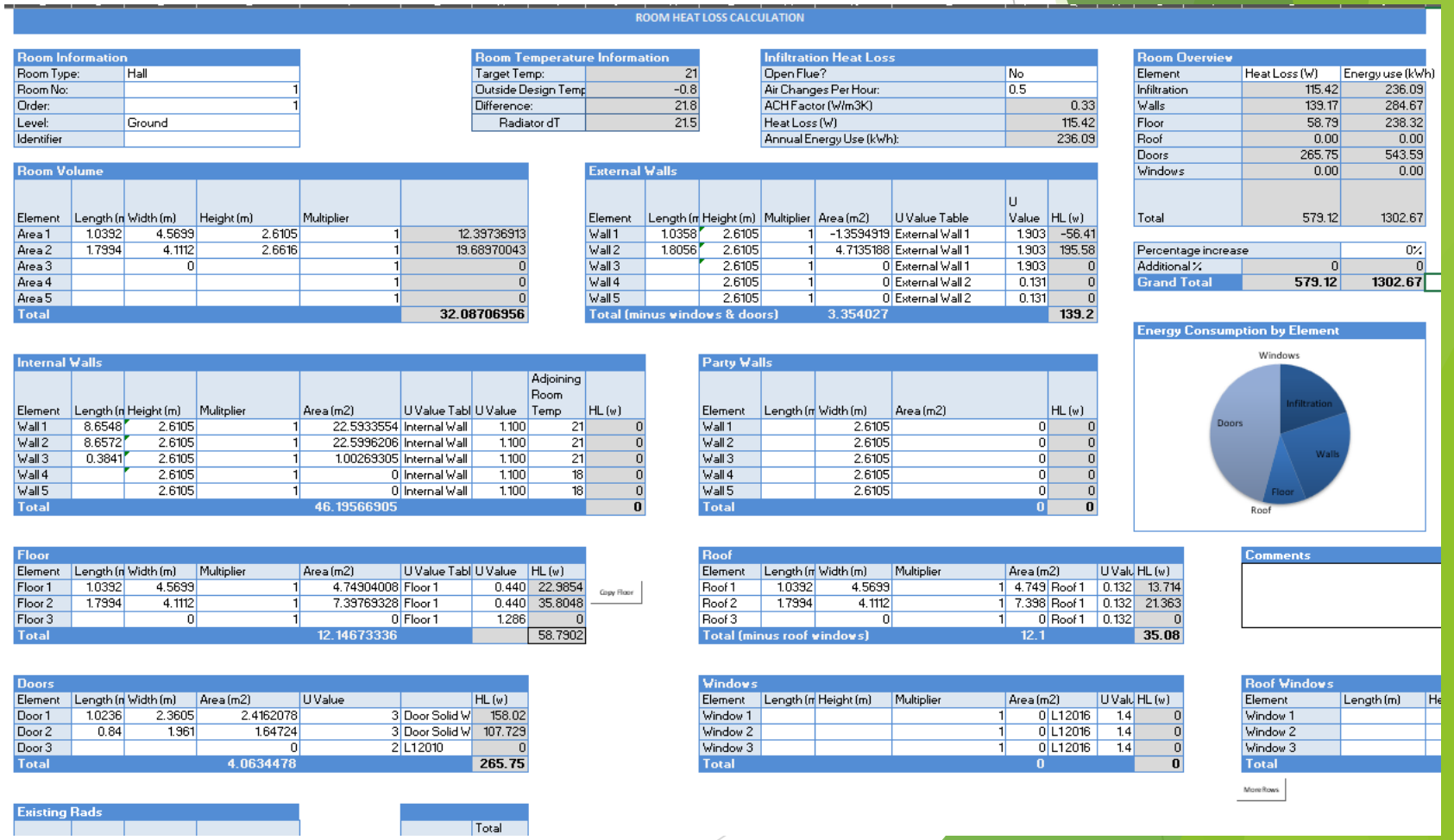
Roof 1			
Material	Thickness	Thermal conductivity (k)	R Value (m2 K /W)
Internal surface (heat flow upwards)	0	0.000	0.100
Gypsum (plaster)	3	0.350	0.009
Plasterboard	12.5	0.190	0.066
Rock wool	300	0.042	7.143
Air Gap	0	0.000	0.180
Roofing felt / bitumen layers	3	0.510	0.006
Slate	15	2.500	0.006
External surface (horizontal heat flow	0	0.000	0.040
-	0	0.000	0.000
-	0	0.000	0.000
-	0	0.000	0.000
Total R Value			**7.549**
U Value (W / m2 K)			**0.132**

The science bit…

Heat Loss Calculations

Process…

- Measure every floor, wall, roof, window and door – every room!



ROOM HEAT LOSS CALCULATION

Room Information

Room Type:	Hall
Room No:	1
Order:	1
Level:	Ground
Identifier	

Room Temperature Information

Target Temp:	21
Outside Design Temp	-0.8
Difference:	21.8
Radiator dT	21.5

Infiltration Heat Loss

Open Flue?	No
Air Changes Per Hour:	0.5
ACH Factor (W/m3K)	0.33
Heat Loss (W)	115.42
Annual Energy Use (kWh):	236.09

Room Overview

Element	Heat Loss (W)	Energy use (kWh)
Infiltration	115.42	236.09
Walls	139.17	284.67
Floor	58.79	238.32
Roof	0.00	0.00
Doors	265.75	543.59
Windows	0.00	0.00
Total	579.12	1302.67

Percentage increase		0%
Additional %	0	0
Grand Total	579.12	1302.67

Room Volume

Element	Length (m	Width (m)	Height (m)	Multiplier	
Area 1	1.0392	4.5699	2.6105	1	12.39736913
Area 2	1.7994	4.1112	2.6616	1	19.68970043
Area 3		0		1	0
Area 4				1	0
Area 5				1	0
Total					32.08706956

External Walls

Element	Length (m	Height (m)	Multiplier	Area (m2)	U Value Table	U Value	HL (w)
Wall 1	1.0358	2.6105	1	-1.3594919	External Wall 1	1.903	-56.41
Wall 2	1.8056	2.6105	1	4.7135188	External Wall 1	1.903	195.58
Wall 3		2.6105	1	0	External Wall 1	1.903	0
Wall 4		2.6105	1	0	External Wall 2	0.131	0
Wall 5		2.6105	1	0	External Wall 2	0.131	0
Total (minus windows & doors)				3.354027			139.2

Energy Consumption by Element

Internal Walls

Element	Length (m	Height (m)	Mulitplier	Area (m2)	U Value Tabl	U Value	Adjoining Room Temp	HL (w)
Wall 1	8.6548	2.6105	1	22.5933554	Internal Wall	1.100	21	0
Wall 2	8.6572	2.6105	1	22.5996206	Internal Wall	1.100	21	0
Wall 3	0.3841	2.6105	1	1.00269305	Internal Wall	1.100	21	0
Wall 4		2.6105	1	0	Internal Wall	1.100	18	0
Wall 5		2.6105	1	0	Internal Wall	1.100	18	0
Total				46.19566905				0

Party Walls

Element	Length (m	Width (m)	Area (m2)	HL (w)
Wall 1		2.6105	0	0
Wall 2		2.6105	0	0
Wall 3		2.6105	0	0
Wall 4		2.6105	0	0
Wall 5		2.6105	0	0
Total			0	0

Floor

Element	Length (m	Width (m)	Multiplier	Area (m2)	U Value Tabl	U Value	HL (w)
Floor 1	1.0392	4.5699	1	4.74904008	Floor 1	0.440	22.9854
Floor 2	1.7994	4.1112	1	7.39769328	Floor 1	0.440	35.8048
Floor 3		0	1	0	Floor 1	1.286	0
Total				12.14673336			58.7902

Copy Floor

Roof

Element	Length (m	Width (m)	Multiplier	Area (m2)	U Valu	HL (w)
Roof 1	1.0392	4.5699	1	4.749	Roof 1	0.132	13.714
Roof 2	1.7994	4.1112	1	7.398	Roof 1	0.132	21.363
Roof 3		0	1	0	Roof 1	0.132	0
Total (minus roof windows)				12.1			35.08

Comments

Doors

Element	Length (m	Width (m)	Area (m2)	U Value		HL (w)
Door 1	1.0236	2.3605	2.4162078	3	Door Solid W	158.02
Door 2	0.84	1.961	1.64724	3	Door Solid W	107.729
Door 3			0	2	L1 2010	0
Total			4.0634478			265.75

Windows

Element	Length (m	Height (m)	Multiplier	Area (m2)	U Valu	HL (w)
Window 1			1	0	L1 2016	1.4	0
Window 2			1	0	L1 2016	1.4	0
Window 3			1	0	L1 2016	1.4	0
Total				0			0

Roof Windows

Element	Length (m)	He
Window 1		
Window 2		
Window 3		
Total		

More Rows

Existing Rads

	Total

The science bit…

Heat Loss Calculations

Process…

- Estimate/measure the air permeability level.

Results

Exponent (n):	0.569
Correlation, r^2:	99.726

Measured Air Permeability

7.75

$m^3/h.m^2@50pa$

Air test carried out in accordance with ATTMA TSL1 standard. All equipment calibrated annually in accordance with UKAS 0807

The science bit…

Heat Loss Calculations

Process…

- Property heat loss = 6.62kW

Room	Heat Loss (W)	Energy (kWh)	Design Temp	Open Flue	ACH	Area (m2)	Volume (m3)	W/m2	kWh/ m2
Dining 1	1429.08	3128.05	21	No	0.5	36.17	92.16	39.51	86.48
Hall 1	579.12	1302.67	21	No	0.5	12.15	32.09	47.68	107.2
Living 1	673.76	1536.98	21	No	0.5	15.98	41.66	42.18	96.21
Study 1	864.85	1857.02	21	No	0.5	16.13	42.50	53.61	115.1
Hall 1	274.99	582.47	21	No	0.5	10.12	24.66	27.18	57.58
Bedroom 1	511.55	1061.47	21	No	0.5	11.71	28.13	43.67	90.61
Bedroom 2	523.28	1105.62	21	No	0.5	16.08	38.27	32.54	68.76
Ensuite 2	159.11	208.58	21	No	1.5	3.56	8.50	44.75	58.65
Bath 1	502.42	889.54	21	No	1.5	7.54	17.88	66.60	117.9
Bedroom 3	522.13	1085.39	21	No	0.5	15.82	37.70	33.01	68.61
Bedroom 4	583.12	1192.78	21	No	0.5	16.85	41.03	34.60	70.77
	6623.42	13950.56				162.11		42.30	85.3

The science bit…

Heat Loss Calculations

Process…

- Property heat loss = 6.62kW
- 6.62kW x 1.2 = 7.92kW

7kW Vaillant Arotherm Plus (R290)

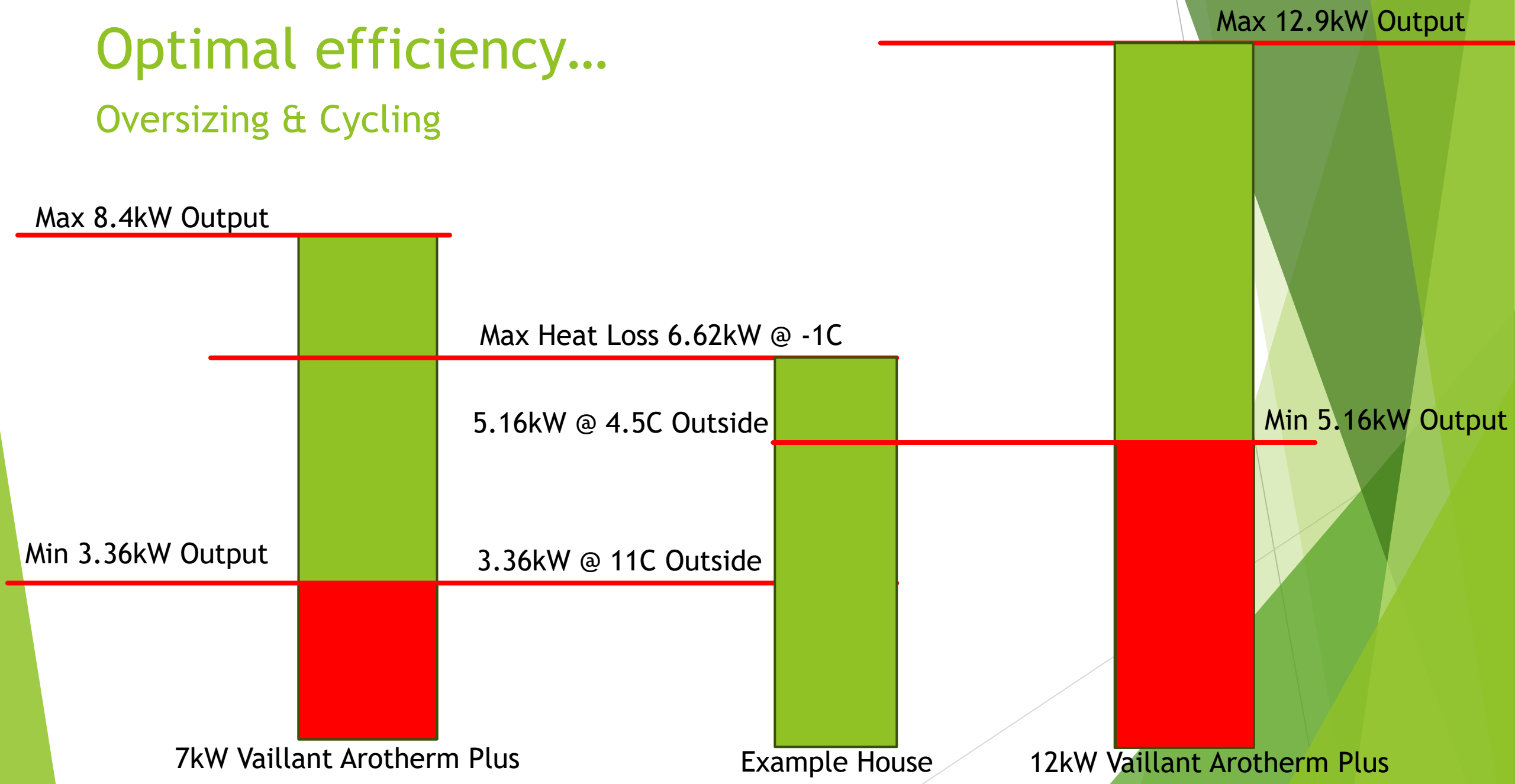
aroTHERM output		35°C flow		40°C flow		45°C flow	
		Output	SCOP	Output	SCOP	Output	SCOP
3.5kW	-5°C	4.2	4.41	4.1	4.03	4	3.65
	-3°C	4.6		4.4		4.3	
	0°C	4.7		4.7		4.6	
	2°C	4.9		4.9		4.9	
5kW	-5°C	6.3	4.48	6	4.13	5.6	3.77
	-3°C	6.8		6.4		6.1	
	0°C	6.9		6.7		6.6	
	2°C	7.1		7		6.9	
7kW	-5°C	8.2	4.36	8.1	4.13	8	3.91
	-3°C	8.8		8.6		8.4	
	0°C	9.5		9.3		9.1	
	2°C	10		9.8		9.6	

How do I get the best efficiency?

Can I beat the manufacturers stated efficiency?

Optimal efficiency…

Oversizing & Cycling



Optimal efficiency…

Radiator Sizing & Flow Temperatures

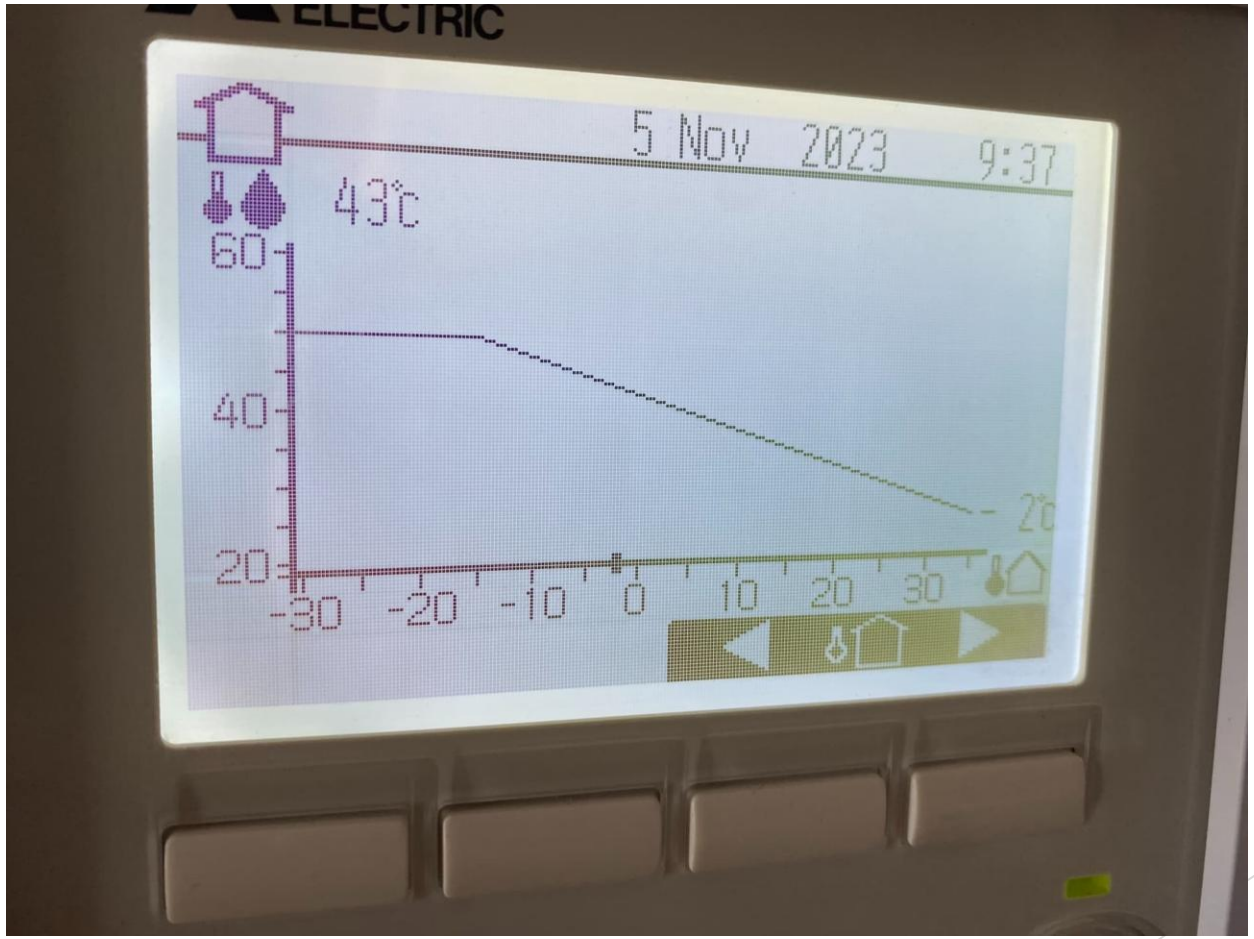
Fossil Fuel Boiler	50-80C
Heat Pump & Radiators	40-50C
Heat Pump & Underfloor Heating	30-40C

Flow Temperature	SCOP
35°C	4.36
36°C	4.32
37°C	4.27
38°C	4.23
39°C	4.18
40°C	4.13

https://mcscertified.com/product-directory/

Optimal efficiency…

Weather Compensation

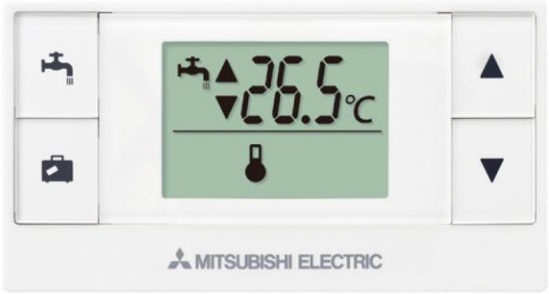


Optimal efficiency…

Controls

Not Recommended

Recommended



Optimal efficiency…

Additional Vessel (buffer tanks, volumisers, low loss headers)

When are they needed…

- Insufficient system volume.
- Significant zoning.
- Oversized heat pump.
- Poorly modulating heat pump.
- Back up immersion capability.

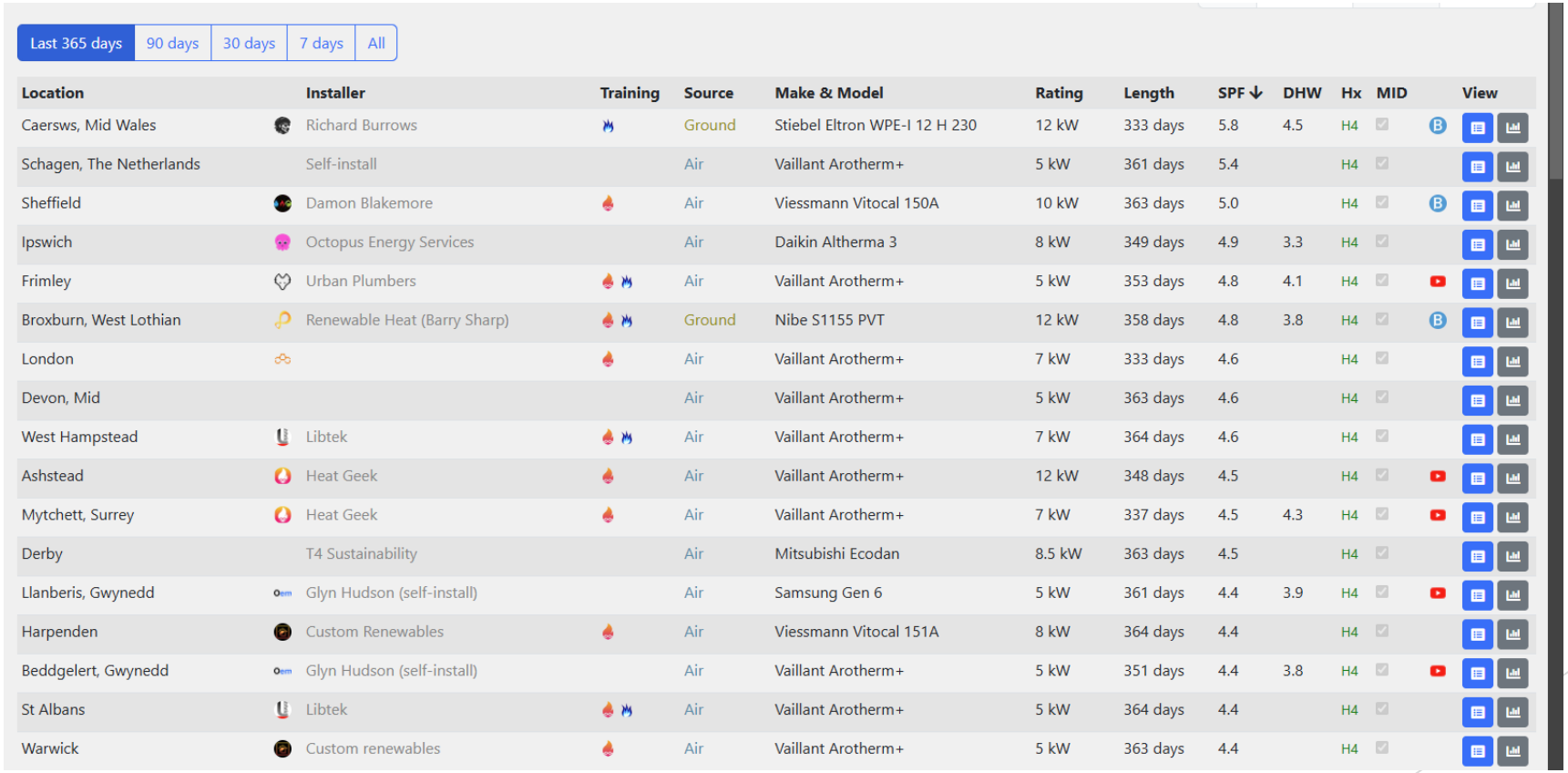
Optimal efficiency…

Heat Periods

24/7 vs ON/OFF

Optimal efficiency…

Heat Pump Monitor - https://heatpumpmonitor.org/



Last 365 days | 90 days | 30 days | 7 days | All

Location	Installer	Training	Source	Make & Model	Rating	Length	SPF ↓	DHW	Hx	MID	View
Caersws, Mid Wales	Richard Burrows		Ground	Stiebel Eltron WPE-I 12 H 230	12 kW	333 days	5.8	4.5	H4		
Schagen, The Netherlands	Self-install		Air	Vaillant Arotherm+	5 kW	361 days	5.4		H4		
Sheffield	Damon Blakemore		Air	Viessmann Vitocal 150A	10 kW	363 days	5.0		H4		
Ipswich	Octopus Energy Services		Air	Daikin Altherma 3	8 kW	349 days	4.9	3.3	H4		
Frimley	Urban Plumbers		Air	Vaillant Arotherm+	5 kW	353 days	4.8	4.1	H4		
Broxburn, West Lothian	Renewable Heat (Barry Sharp)		Ground	Nibe S1155 PVT	12 kW	358 days	4.8	3.8	H4		
London			Air	Vaillant Arotherm+	7 kW	333 days	4.6		H4		
Devon, Mid			Air	Vaillant Arotherm+	5 kW	363 days	4.6		H4		
West Hampstead	Libtek		Air	Vaillant Arotherm+	7 kW	364 days	4.6		H4		
Ashstead	Heat Geek		Air	Vaillant Arotherm+	12 kW	348 days	4.5		H4		
Mytchett, Surrey	Heat Geek		Air	Vaillant Arotherm+	7 kW	337 days	4.5	4.3	H4		
Derby	T4 Sustainability		Air	Mitsubishi Ecodan	8.5 kW	363 days	4.5		H4		
Llanberis, Gwynedd	Glyn Hudson (self-install)		Air	Samsung Gen 6	5 kW	361 days	4.4	3.9	H4		
Harpenden	Custom Renewables		Air	Viessmann Vitocal 151A	8 kW	364 days	4.4		H4		
Beddgelert, Gwynedd	Glyn Hudson (self-install)		Air	Vaillant Arotherm+	5 kW	351 days	4.4	3.8	H4		
St Albans	Libtek		Air	Vaillant Arotherm+	5 kW	364 days	4.4		H4		
Warwick	Custom renewables		Air	Vaillant Arotherm+	5 kW	363 days	4.4		H4		

Dartmoor Energy

How we can help…

- Heat pump quotes – trusted installer network
- Independent heat loss reports.
- Independent system design.
- Independent air pressure testing.
- Whole house energy efficiency reports.

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