humblebee

Carbon Coop Webinar Series, September 2020

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DESIGNER CERTIFIED PASSIVHAUS DESIGNER

AECB building knowledge

PEOPLE POWERED RETROFIT

Heat Pumps

6 things you need to bear in mind if you're considering a heat pump for your home

What are the 6 things to bear in mind?

1. Not a boiler
2. What do I need to do to my house to make it heat pump-ready?
3. All these components - do I have space? Do I have the budget?
4. I’m going for it, what next? How big? How do I get help? How do I buy it?
5. So many types – what’s best for my needs?
6. Install, operate, monitor.

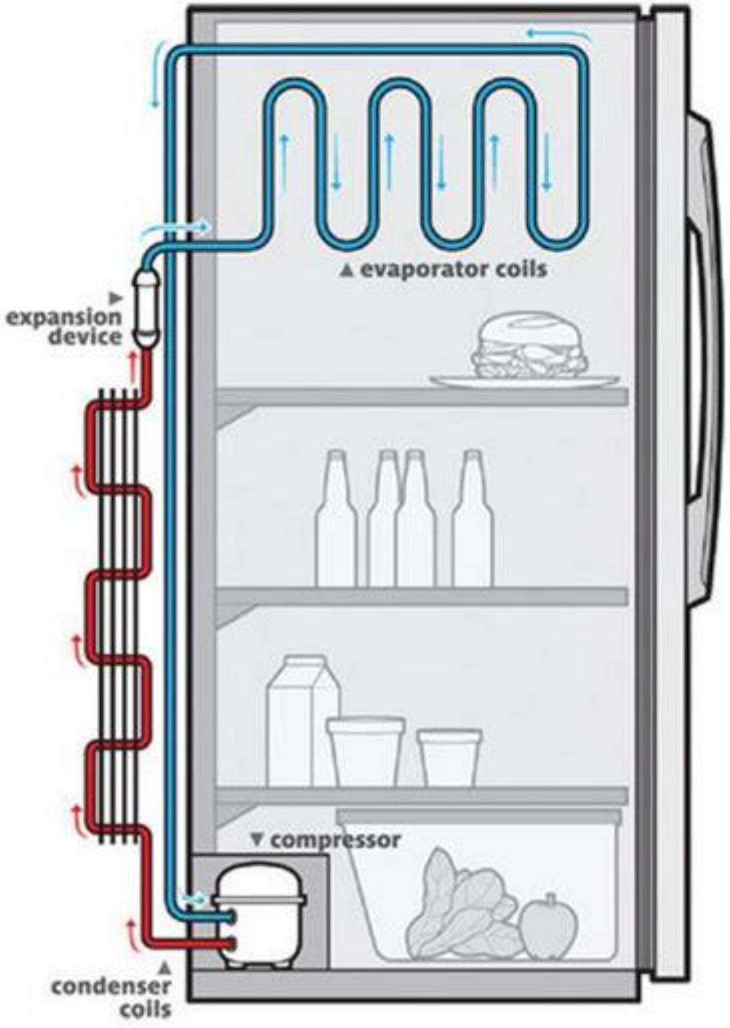
1. A heat pump is not a boiler

So how does it work?

What is a Heat Pump

How does your fridge work?

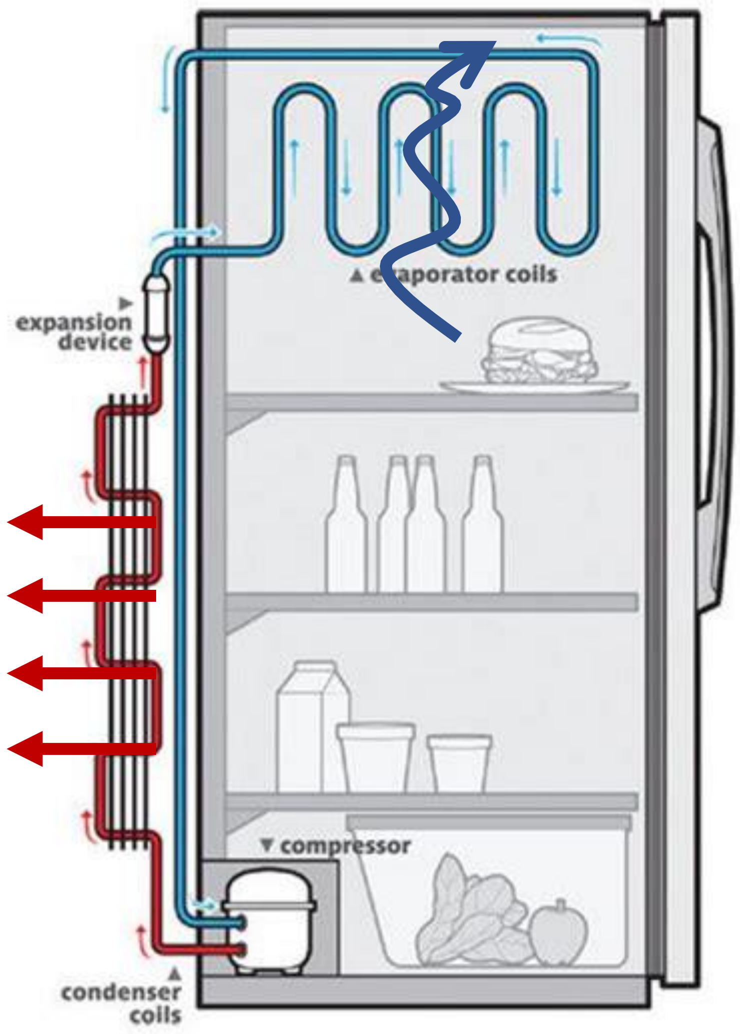
- The aim is to cool food stored inside the refrigerator and maintain it at that temperature
- A refrigerant is pumped between two zones that are at different temperatures
- There are 4 main components: compressor, condenser coil, expansion valve, evaporator.
- Electrical energy (work) is put into the compressor.



What is a Heat Pump

How does your fridge work?

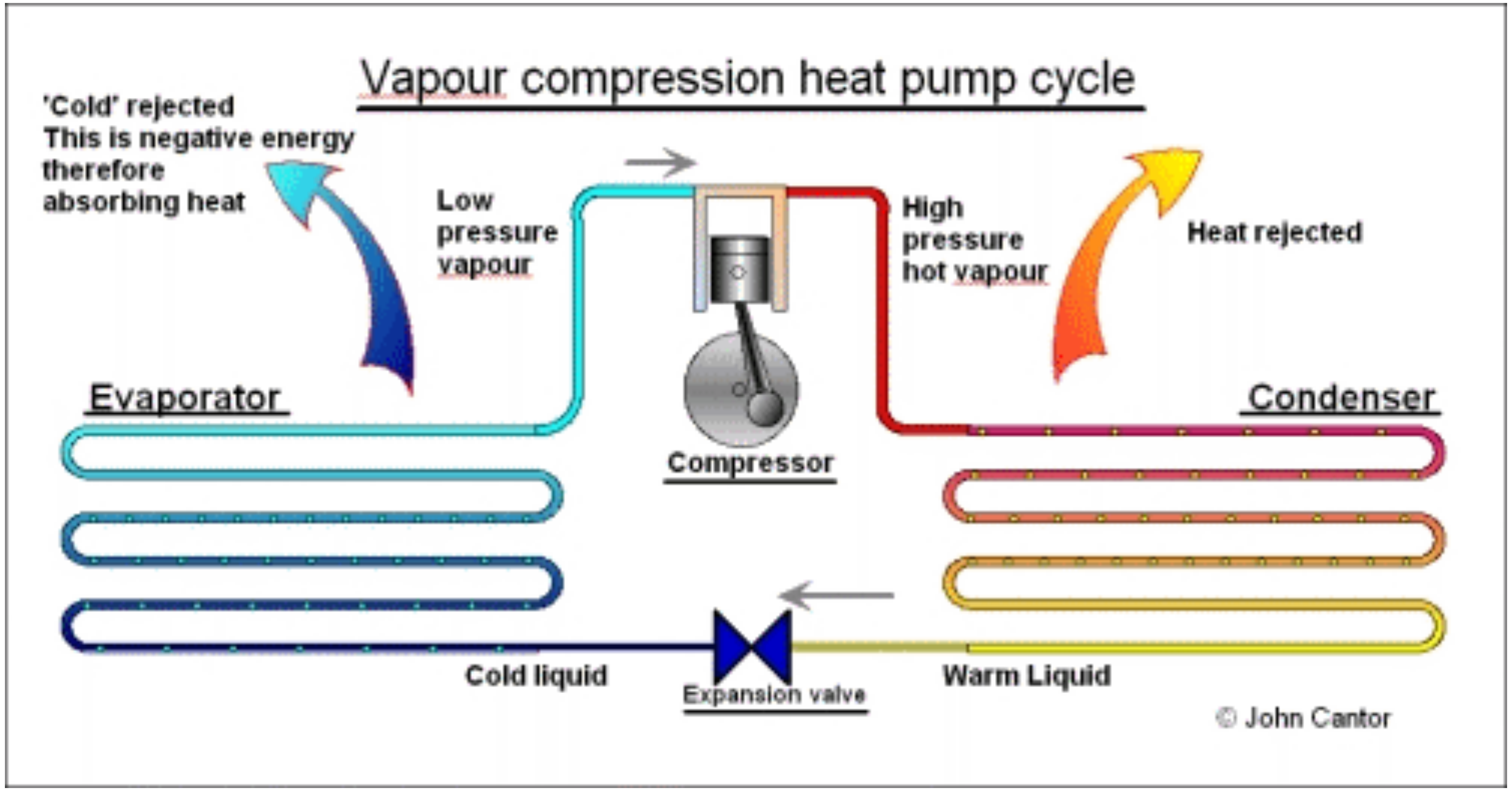
- As hot refrigerant liquid passes through the expansion valve its pressure is reduced, causing it to become cool and starting the transformation of refrigerant liquid to gas
- Heat is taken out of a low temperature zone by continuing to evaporate the refrigerant
- The compressor forces the gas to a higher pressure state (driving force)
- It's "rejected" to surrounding air at a higher temperature by virtue of condensing the refrigerant gas (at the back of the fridge).



What is a Heat Pump

How does a HP work?

- Reverse fridge cycle
- "Air Source" extracts heat from ambient air - ASHP
- "Ground source" extracts heat from ground – GSHP
- Components the same



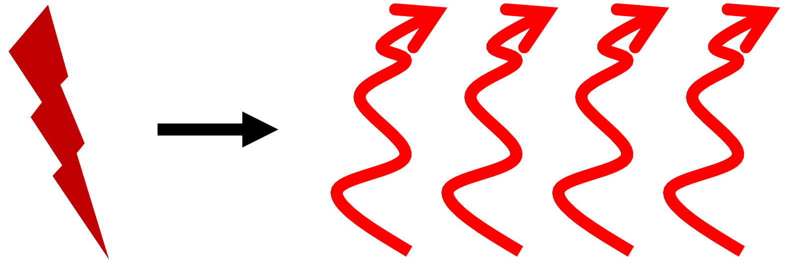
Heat Pump Installation Types

- Ground source and air source
- Monobloc (single & double)
- Split (single & double) and air-to-air

- Outdoor Unit - positioning
- Indoor Unit + Buffer tank (optional)
- Expansion vessel
- Hot Water Cylinder
- Possible integration with renewables

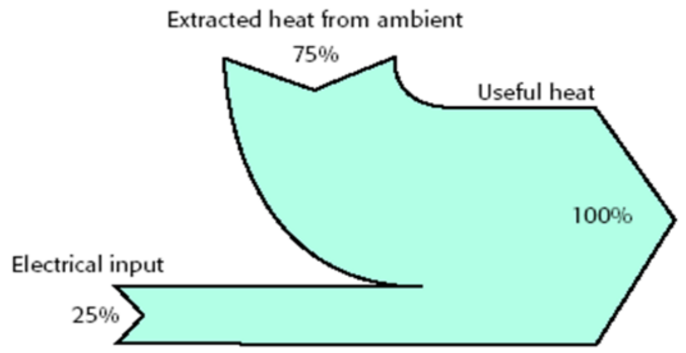
Heat Pump Efficiencies

- COP = Coefficient of performance



1 kW (Elec) IN → 4 kW (Heat) OUT
i.e. COP = 4

- SPF = Seasonal Performance Factor



Heat Pump Efficiencies

ASHP used in winter to heat bath water

Source temperature -5°C, output temperature 55°C → COP 1.5

ASHP used in summer to heat swimming pool

Source temperature 20°C, output temperature 30°C → COP 5

GSHP (shallow) feeding underfloor heating system

Source temperature 5°C, output temperature 35°C → COP 4

GSHP (shallow) feeding Low temperature radiators

Source temperature 5°C, output temperature 45°C → COP 3

$$\text{COP (Carnot)} = \frac{T_C}{(T_H - T_C)}$$

(T in degrees Kelvin)

Traditional boiler installation

- Condensing or not, boilers tend to be 20kW+ to overcome typical heat losses from the dwelling
- Combi boilers may be rated higher to provide instantaneous hot water
- Operating temperatures are usually 60-80^{o}C, and that's the basis for existing radiator sizes
- **Typical heat losses from UK dwellings (@20degC internal temperature): 150-250kWh/m^{2}.a**

Heat pump installation

- A heat pump could in theory deliver same amount of heat as a boiler
- It would be a very large installation with poor efficiencies because sized for the peak and then inefficient the rest of the time at part load
- Electricity is usually about 2.5-3x cost of gas. Even accounting for boiler losses, in order for a heat pump to be efficient and cost effective to run, you would want to aim for average COP 2.5-3 as a minimum
- Hot water system design key to keeping size down
- Operating temperatures are usually 30-50°C, which means radiator need to be larger to deliver the same output.
- **But by significantly reducing heat losses from the home, and designing the hot water system appropriately, machine size can be kept low.**

- Is my home suitable for a heat pump? Good blog post here:

https://www.enhabit.uk.com/2020/04/02/is-my-house-suitable-for-an-air-source-heat-pump/

Operating Temperatures

Operating temperatures and heat emitters

- Difference in temperature between average operating temperature of panel and room air = ΔT 20K
- Compared with ΔT 50K for medium temperature boiler system.

What does this mean…?

What would you end up with...?

What would you end up with...?

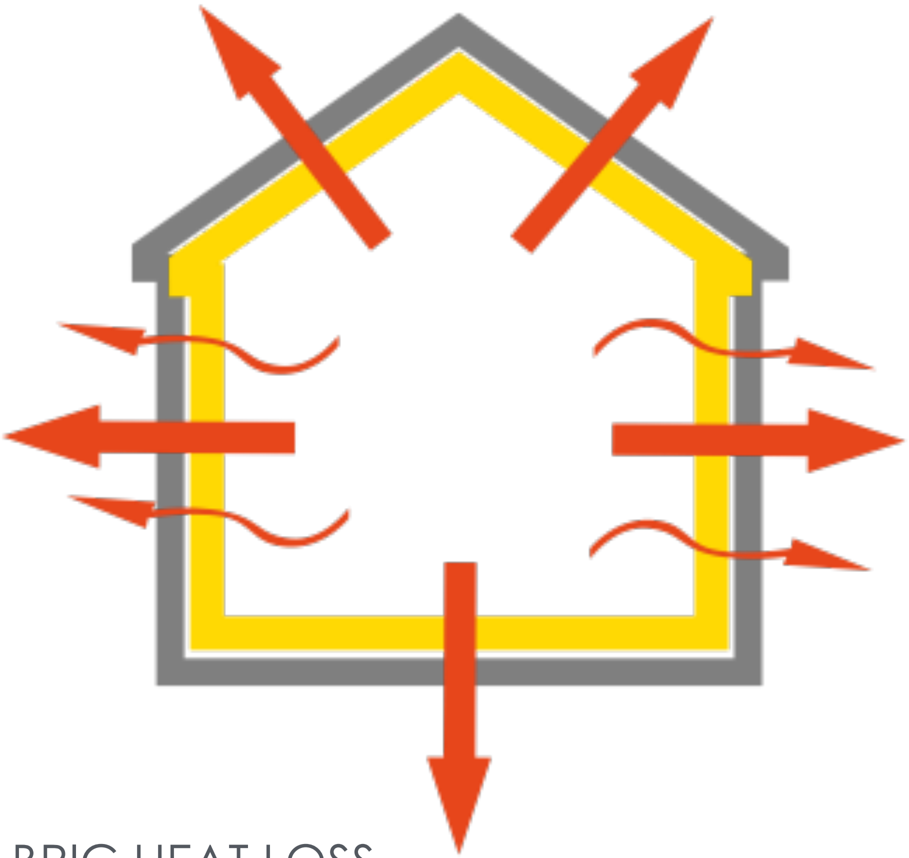
What would you end up with...?

What would you end up with...?

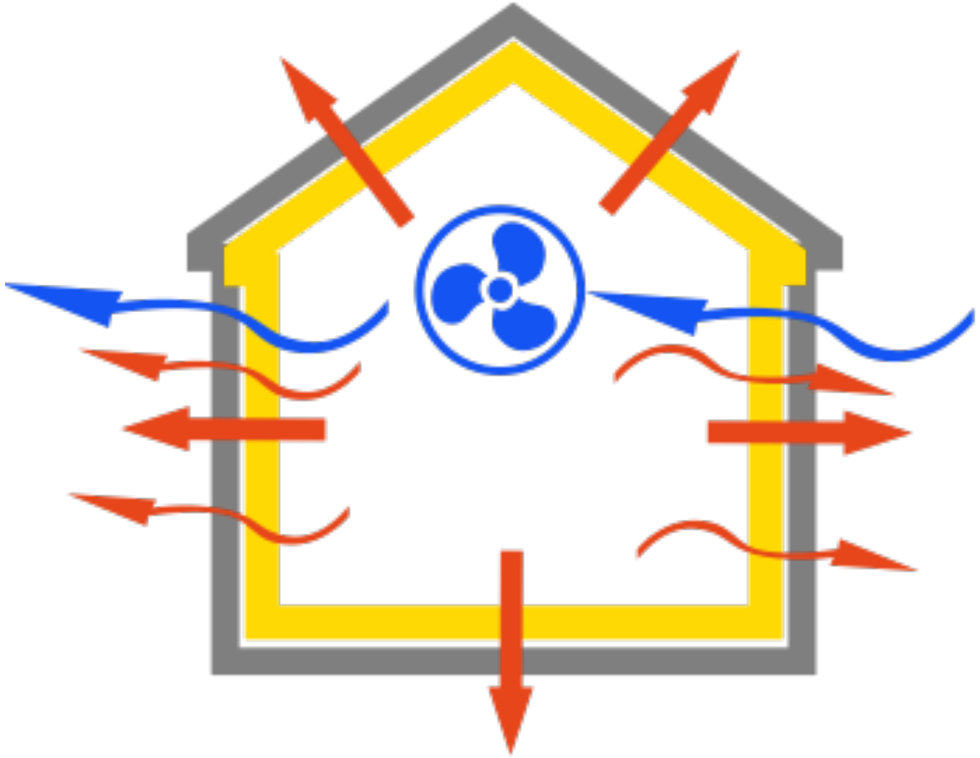
2. How can I be heat pump-ready?

Whole house energy retrofit

The home as a system....

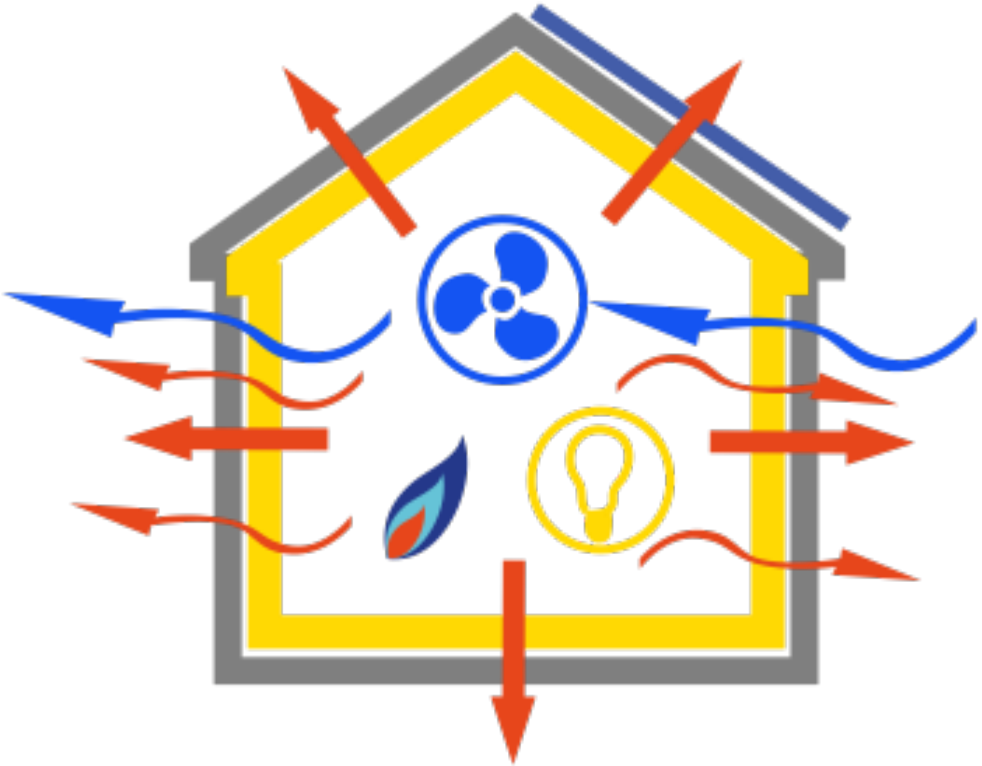


FABRIC HEAT LOSS

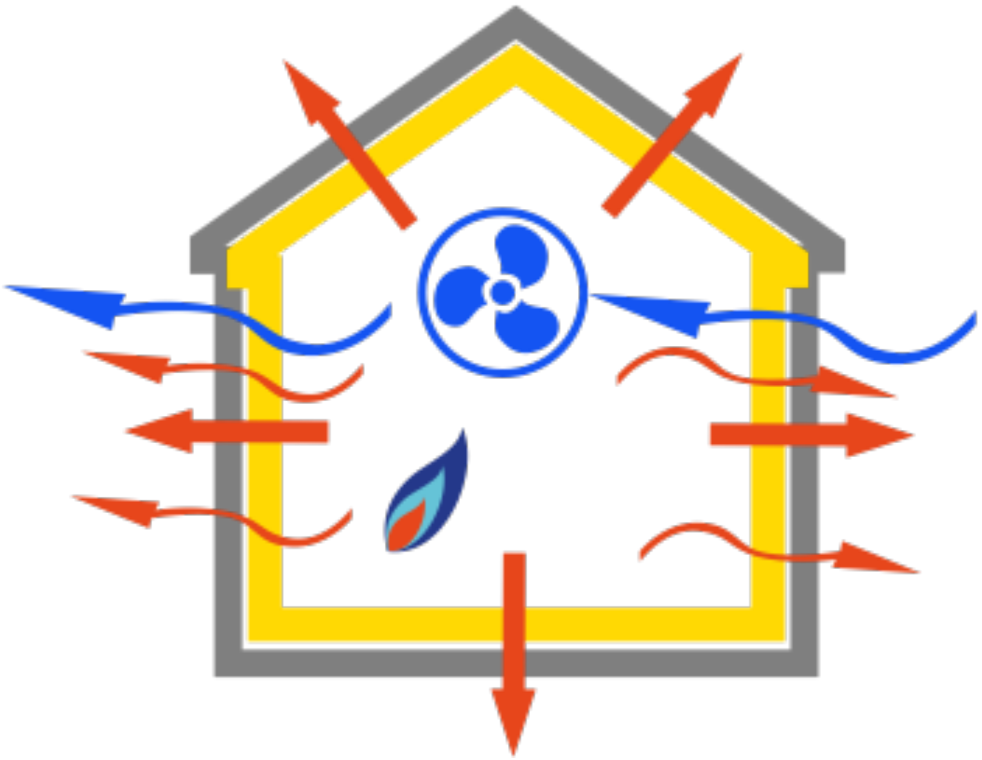


+ VENTILATION

The home as a system....



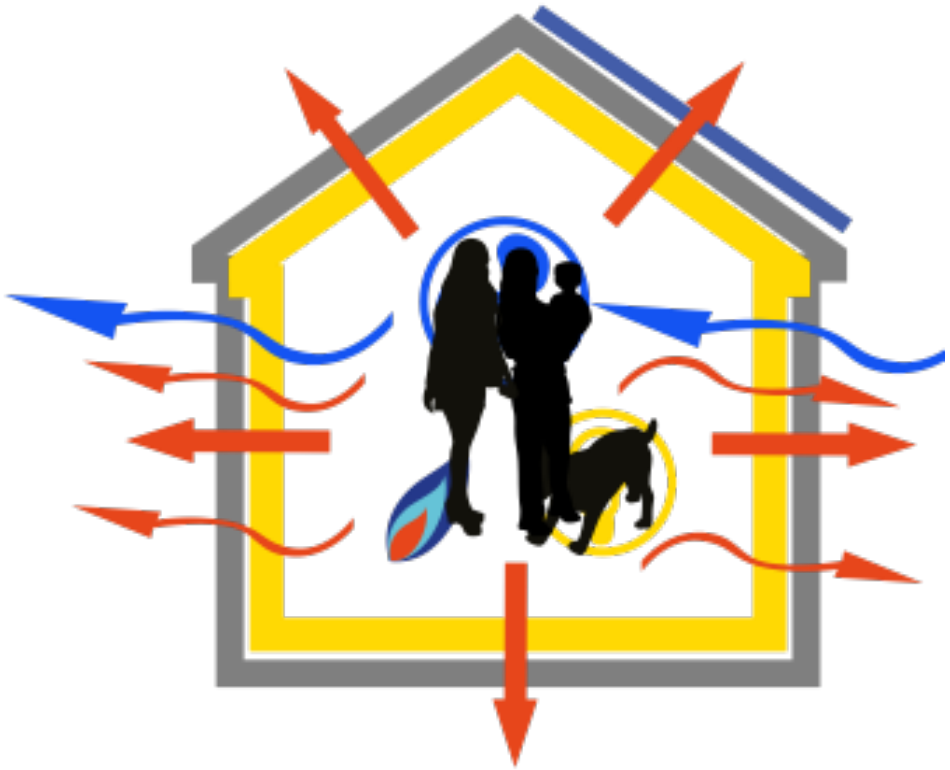
+ INTERNAL GAINS (LIGHTS, APPLIANCES,...)



+ HEATING SYSTEMS

The home as a system….

….and all of these systems interact. Sometimes in ways that are easy to understand, but hard to predict in detail in a given circumstance.



+ PEOPLE!!

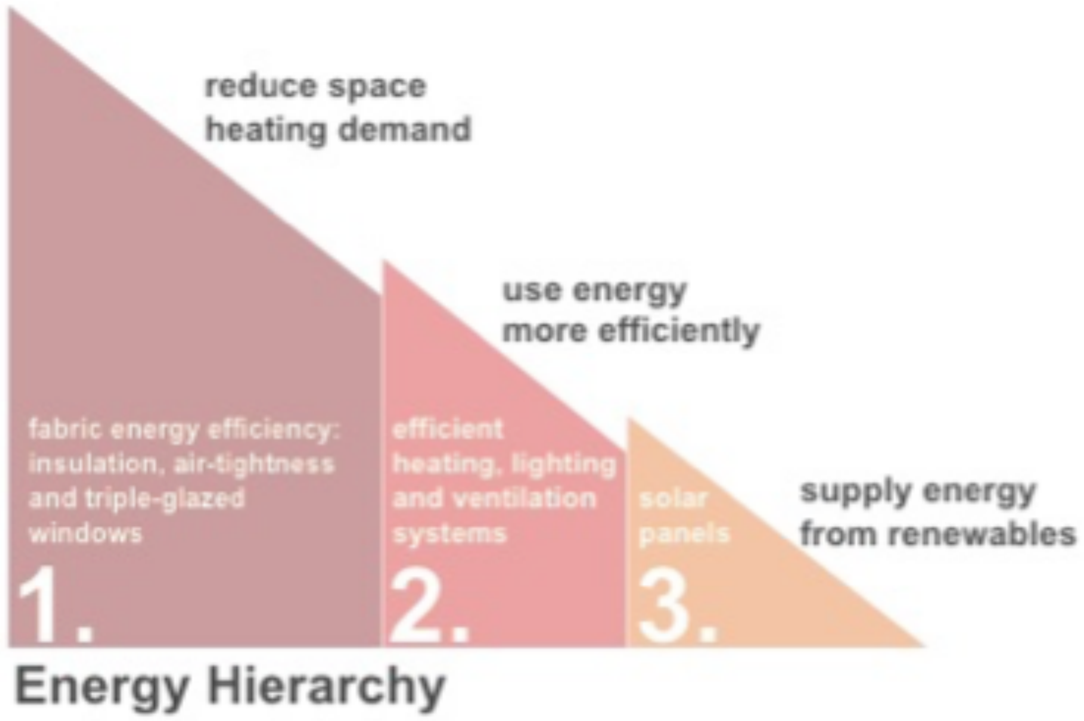
Whole house approach to retrofit….

We take a ‘Fabric First’ approach, and avoid ‘eco-bling.

This has been shown by post-completion monitoring to be what works - reducing the ‘performance gap’ between intentions and outcomes.

It has lots of ‘co-benefits’ - insulation makes you warmer, as well as reducing energy use!

It also makes it easier to meet more stretching targets - your building services then have to do less work.



How low do you go?

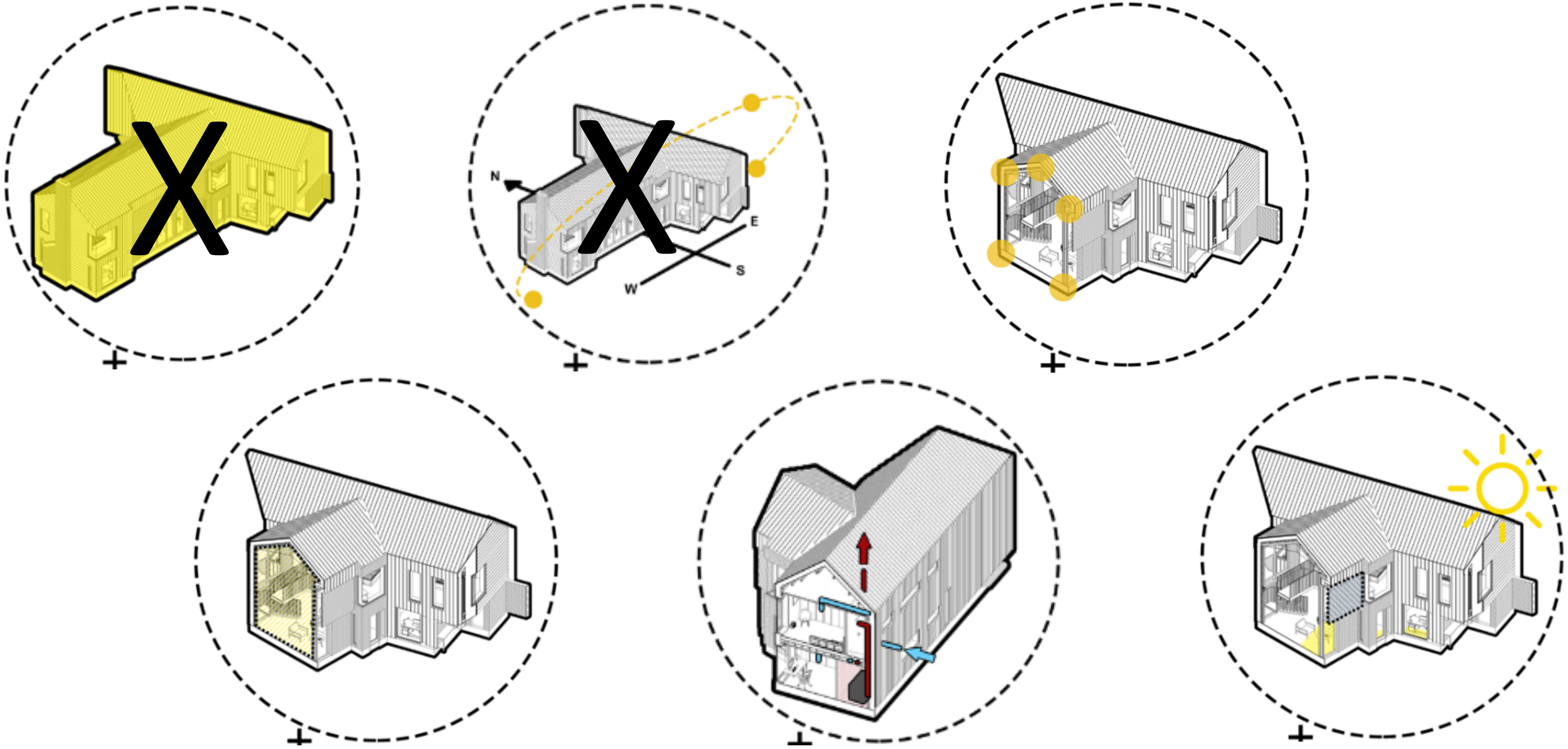
UK average (for house type): **140 kWh/m2.a**

EnerPHit – Building Energy Performance

- Specific heating demand **≤ 25kWh/m²^2.yr**
- Specific peak heating load **approx. 25-40 W/m^2**

Low Energy House
(e.g. AECB standard) **25-45kWh/m2.yr**

EnerPHit - Passivhaus in retrofit?

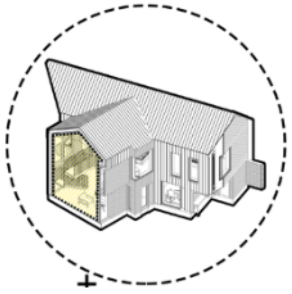


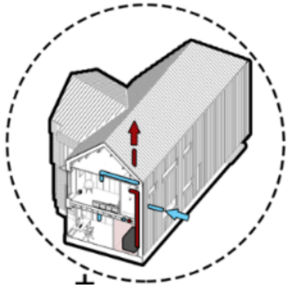
Diagrams care of QODA Consulting

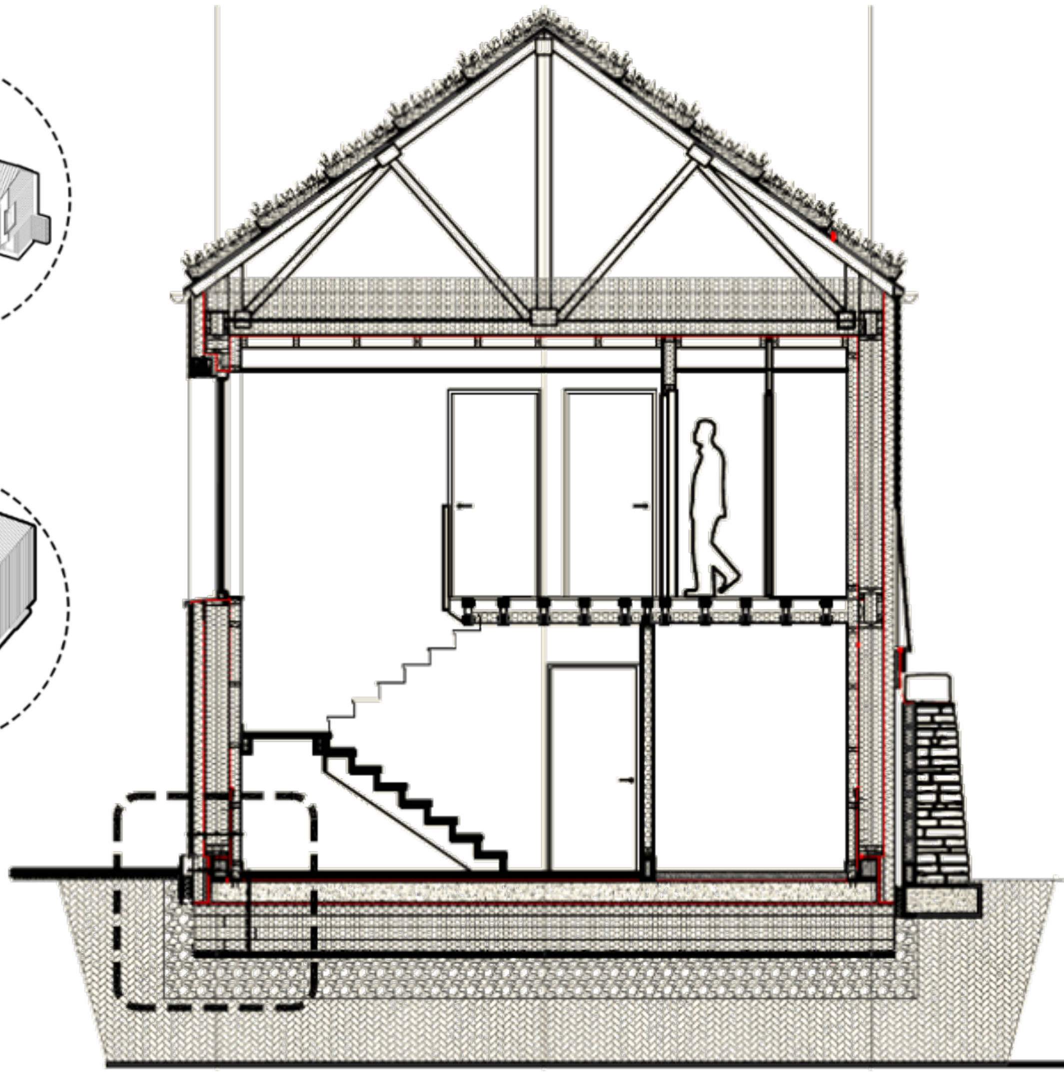
Airtightness and ventilation

Air leakage at 50 Pascals (positive and negative pressure)

- ≤1 air change per hour (retrofit)
- Continuous barrier to passage of air
- Wraps around building
- In the right place at the insulation layer to avoid condensation







Mechanical Ventilation with Heat Recovery (MVHR)

- Heat recovery rate **≥ 75%**
- Specific fan power **≤ 0.45 Wh/m3**
- Maximum noise level from unit **35dB(A)**

Diagrams care of QUODA Consulting

But…

- …perfect is the enemy of good. *Voltaire, quoting "a wise Italian"*

Not everyone will have the budget to do the maximum, so:

- Aim to do as much as you can afford
- And the things you do, do them to the best of your (or your chosen builder/installer's) abilities.
- And that means talking to them, making them understand your exacting requirements and checking workmanship.

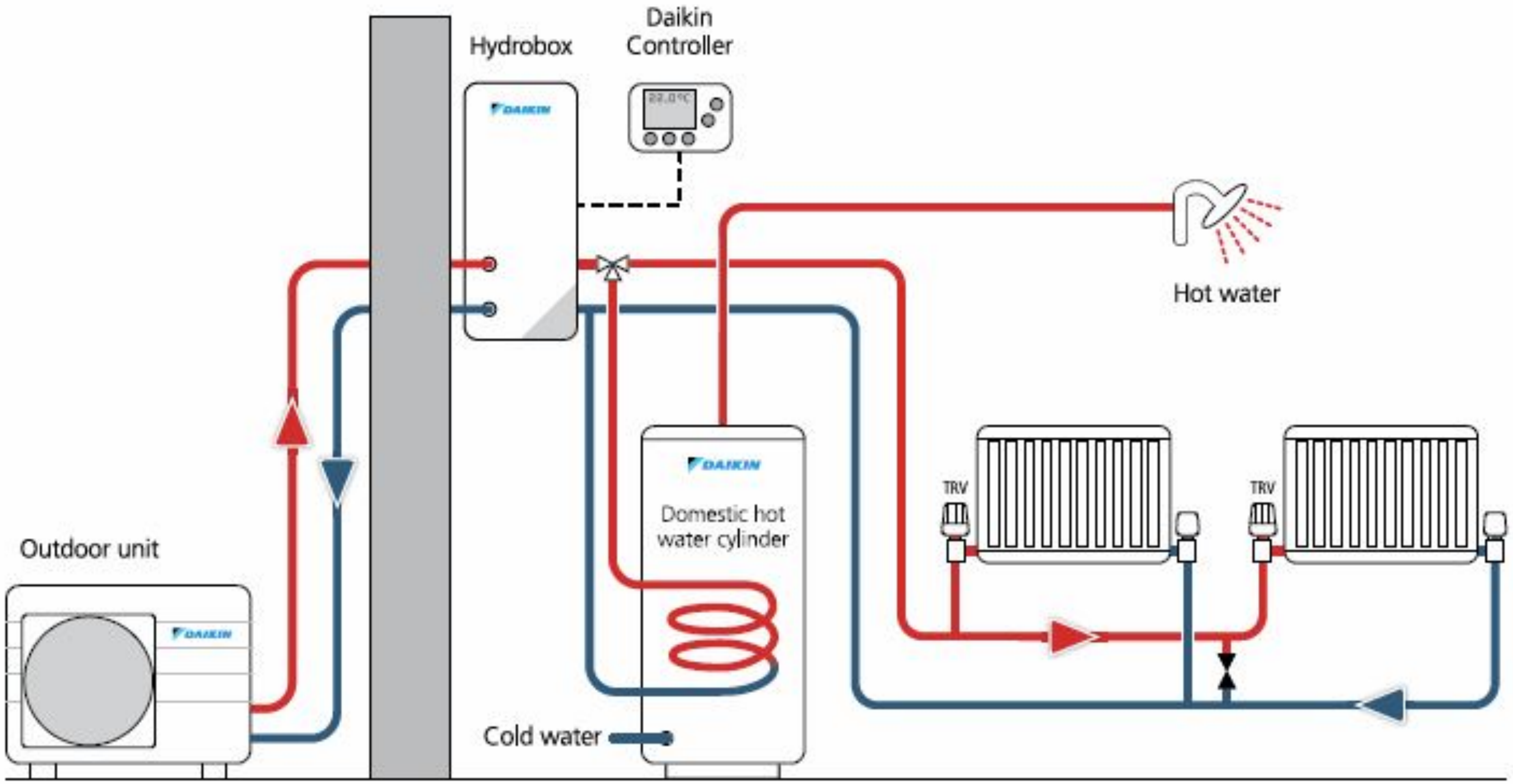
3. Do I have space? Do I have the budget?

Components and location, costs and grants

Where to locate?

- Monobloc: all heat pump is in one external unit, restricted distance, max 12m
- Split system: internal and external units (max distance more like 50m, but refrigerant pipework between: needs F-gas registered installer) – suitable for larger houses
- Must locate a domestic hot water cylinder/thermal store somewhere close to the unit (can't have instantaneous hot water like a combi).
- Buffer tank, water filter, pump and expansion vessels

Example of an ASHP system



How much does it cost?

- Depends on HP size
- Depends very much on extent of system installation (HP, hot water cylinder, new radiators to suit, controls and monitoring)
- Depends on warranties
- Depends on whether you go for grants: this tends to push the prices up
- Price range appears to be £5,000 - £14,000.

Renewable Heat Incentive

Eligibility Criteria

https://www.ofgem.gov.uk/environmental-programmes/domestic-rhi/

Air source heat pump

Hide

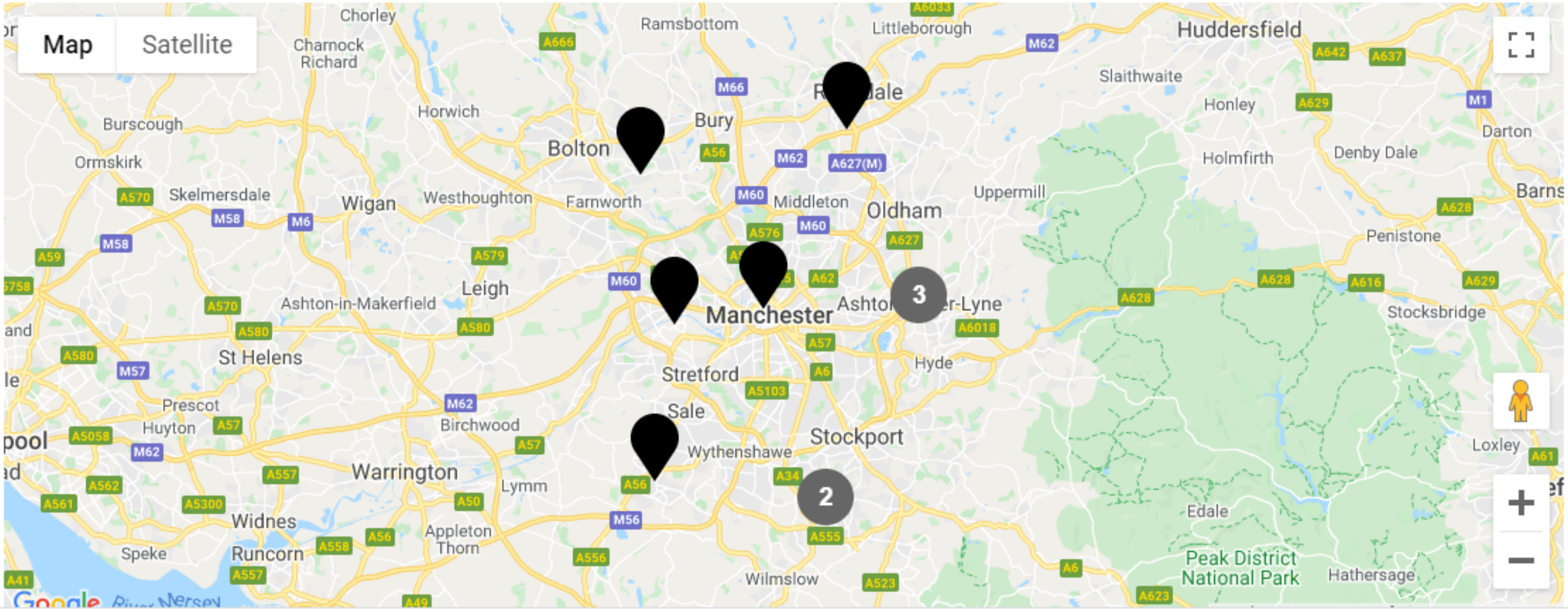
Eligibility requirements	Eligible uses	Ineligible uses
Must use a compressor driven by electricity	Space heating (SH) only, or both space and Domestic hot water (DHW) heating.	Designed to use heat from air expelled from an appliance or building when generating heat
Must use a liquid to provide space (eg, room) heating	Heat pumps don't have to provide domestic water heating to be eligible, but may do so (They may also provide water cooling).	Domestic hot water (DHW) doesn't include space heating (including heat dumps) or swimming pool heating.
Must have a minimum Seasonal Performance Factor (SPF) of 2.5		

Renewable Heat Incentive

- Eligibility also dependent on carrying out insulation work (e.g. cavity or loft insulation).
- Recent EPC (less than 2 years)
- Grant of approximately £6,000 – £12,000
- Grant is paid back over 7 years, calculated on rate per kWh applied to (the renewable portion of) your yearly consumption
- Grant capped at 20,000kWh / year consumption
- MCS accredited installer

Showing: 10 nearest installers to Manchester, UK

MAP VIEW | **LIST VIEW** | **1 SHOW FILTERS** | **SHOW NEAREST** 10



Green Homes Grant Scheme

When can members of the public start applying?

From now (September 2020), homeowners across England should be able to access advice and support on improving the energy efficiency of their homes from the Simple Energy Advice service.

The government will provide a voucher (up to £5,000) that covers up to two thirds of the cost of qualifying improvements to your home.

The Simple Energy Advice will offer households a list of approved TrustMark Registered Businesses including those approved via the Microgeneration Certification Scheme (MCS) scheme in their local area to carry out the work.

https://www.simpleenergyadvice.org.uk/pages/green-homes-grant

What energy efficiency measures does the grant cover?

1. Solid wall, under-floor, cavity wall, loft, flat roof, room in roof or park home insulation, ventilation; or

2. Air source or ground source heat pump or solar thermal (where the home is suitably insulated).

In addition, households can use their voucher for further energy saving measures, up to the value of 50% of the voucher.

- Draught proofing
- Windows and doors
- Heating controls and heating systems insulation.

Viability

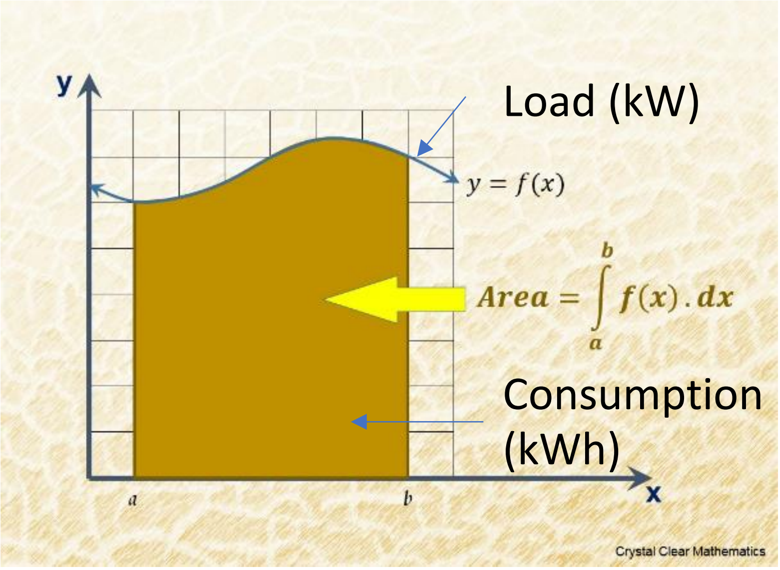
- Outdoor and indoor space available?
- Outdoor noise criteria
- Radiator sizes
- Accompanying retrofit measures, including mechanical ventilation
- Costs and cashflow
- Switching from gas difficult economically in current market conditions (switching from oil is definitely viable)
- Justified by looking at CO2 equivalent emissions avoided through retrofit and efficient ASHP design, and added comfort of holistic retrofit.

4. I’m going for it, what next?

How do I get help? How do I buy it? How big?

Peak heat load and energy consumed

- Peak heat load is what gives you the size of your heat source
- It's how much heat is needed to counter the heat losses from your home on a peak condition day and is "work" or "power", in kW
- It's not necessarily what you use all the time, as you can see on the graph.
- Energy consumed is the area under the curve and is represented by bars in kWh.
- Therefore, you can't work back from your annual gas bills or kWh to find the peak

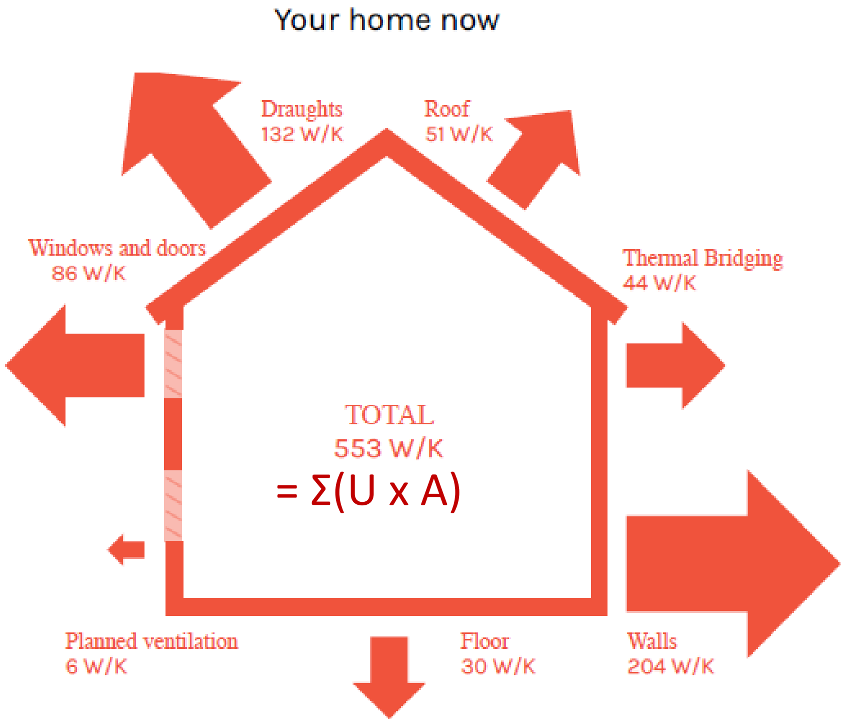


How do we determine peak load: heat losses

- A U-value is rate of heat loss per sqm of wall/floor/roof per degree difference in temperature between inside and out.
- You need to know the materials, their thickness (m) and their thermal conductivity (lamda, in W/mK), and build up the construction elements (you can't add U-values together, only their inverse)
- Don't forget ventilation heat loss/infiltration.

Then you'll need:

- Areas of each heat loss element (external walls, roof, floor)
- Difference in temperature outside to in, dT (design outside T in Manchester is -4°C, as per CIBSE Guide A) – (note: based on a % exceedance of historical data)



$Q_H = \Sigma(U \times A) \times dT$

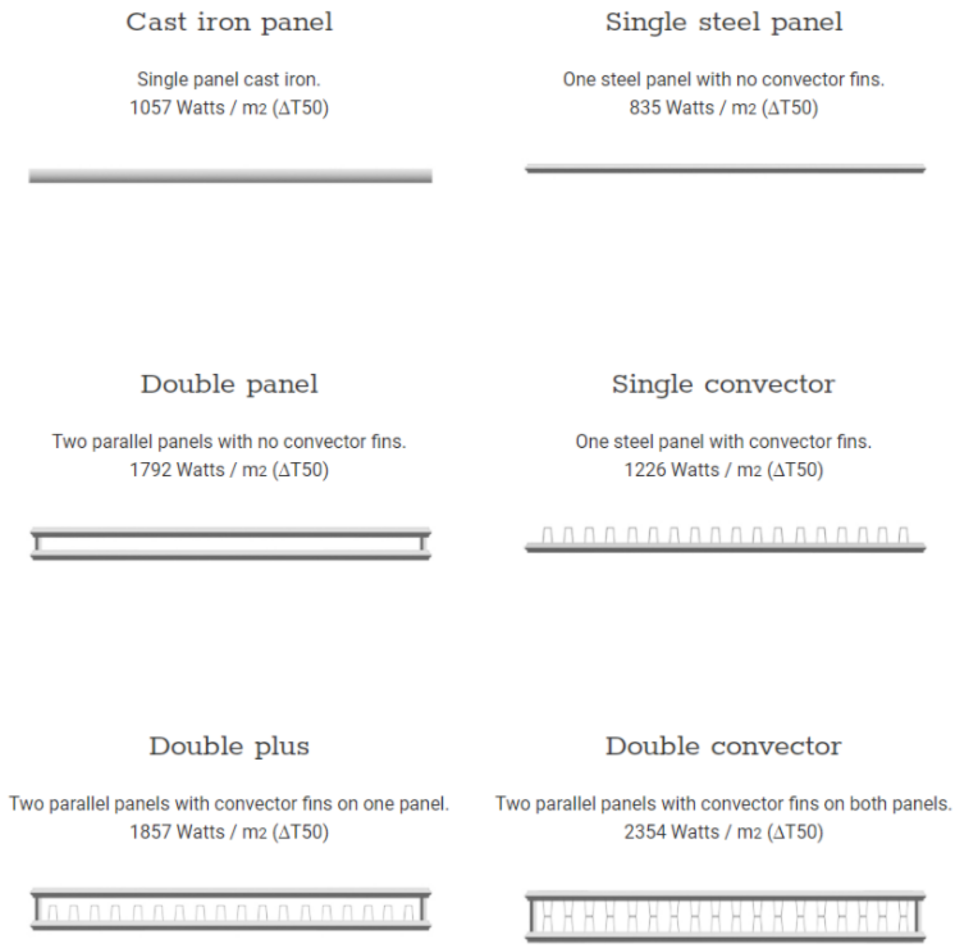
Emitter sizing

Calculate your heat losses room by room.

Check your radiator types and sizes with typical boiler installations (@ dT 50).

Then look up a radiator data sheet to find equivalent output @ dT 20 as output not proportional to dT.

For underfloor heating, work out the room by room heat losses and send to a UFH supplier.



Source: https://www.castrads.com/uk/resources

Domestic Hot Water (DHW) options

1) Unvented cylinder, sized based on number of bathrooms/ people

- Ideally use correct (optimised) type, or external heat exchanger like the Mixergy tank – may need to be bespoke size to fit in available space
- Requires legionella control (raise temperature to 60°C for one hour once a week)
- Mains pressure or pumped delivery, or manifold & small bore pipework reduces delay to taps.

2) Thermal store, indirect DHW delivered, legionella control not necessarily required

- Can use multiple sources to "dump" excess energy (solar thermal, solar PV, and as a heat pump buffer)
- Like hot water delivered by combi-boiler, but small bore pipework can also be used to reduce delay to taps
- https://heatpumps.co.uk/types-of-heat-pump/domestic-hot-water-dhw/

DHW Cylinder Sizing

The power needed for hot water heat-up is energy input to raise temperature, divided by time taken to heat up volume of water.

Variables are – the key is in choosing these:

- Water volume, V
- Temperature difference incoming (10°C) to storage temperature, dT
- Time for heat up (seconds, convert to minutes or hours), min or h

Use correct units and constants!

Sizing for domestic hot water (DHW):

4No 5min Showers[1]	4No 35L showers	180L (full) Warm bath
120	140	134

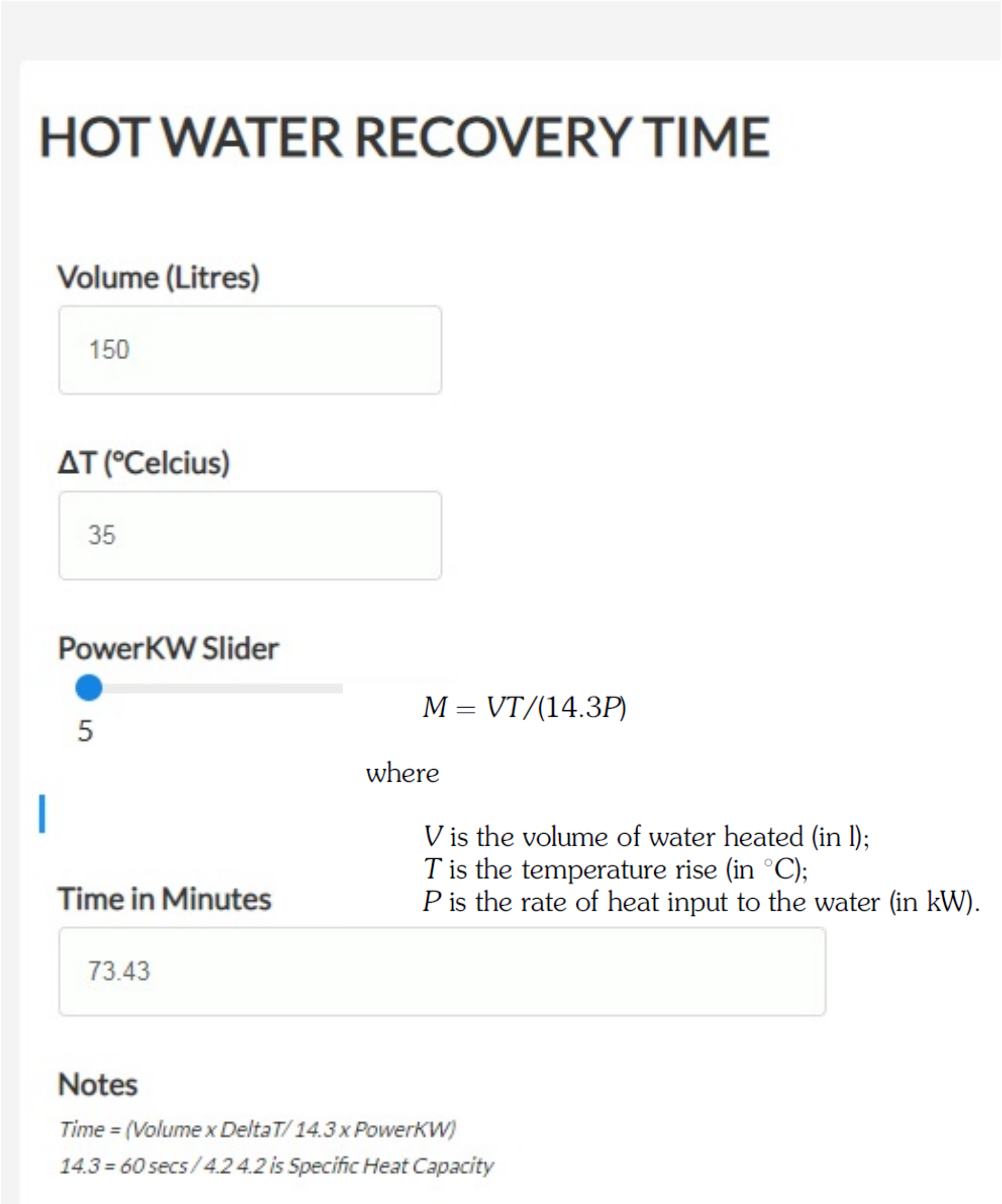
[1] assumes 6 l/min (low flow) shower heads

DHW Cylinder Sizing

Or you can do it iteratively using this online calculator for example

https://myboiler.com/calculators/hot-water-recovery-time-calculator/

myboiler



5. So many types – what's best for my needs?

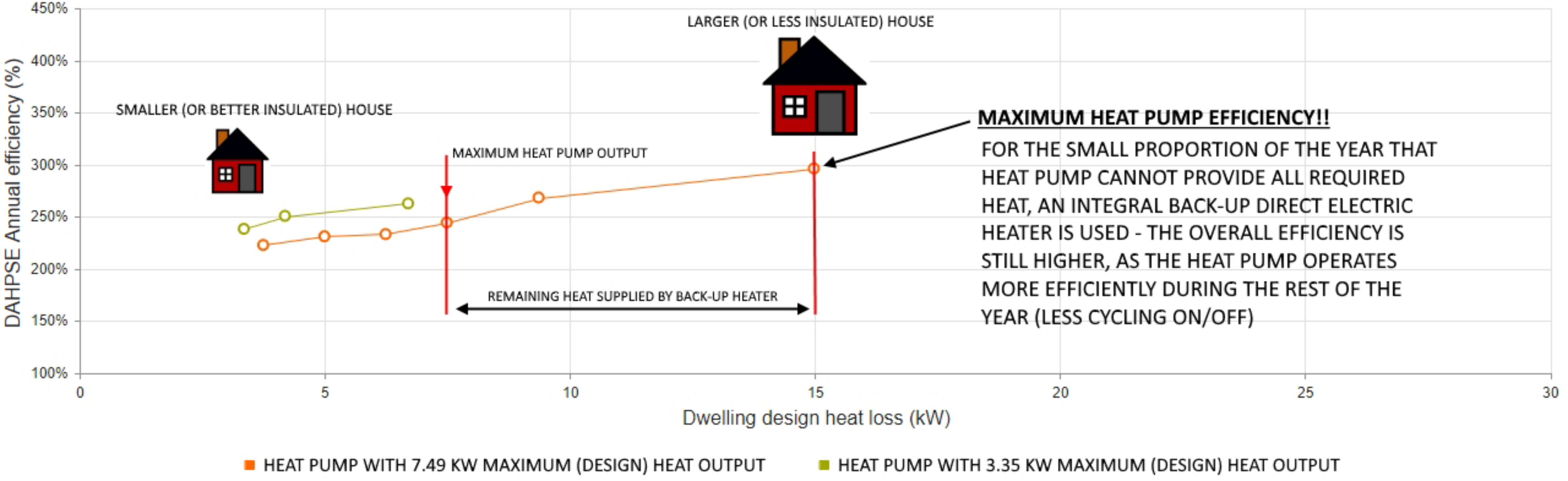
Choosing best matched system and model

Choosing model and installer

1. Decide type, make, model
2. Choose installer
3. Design system (an engineer should do this part)
4. Install
5. Commission / operate

As one of our experienced members says, you need to get all 5 right!

Compare models



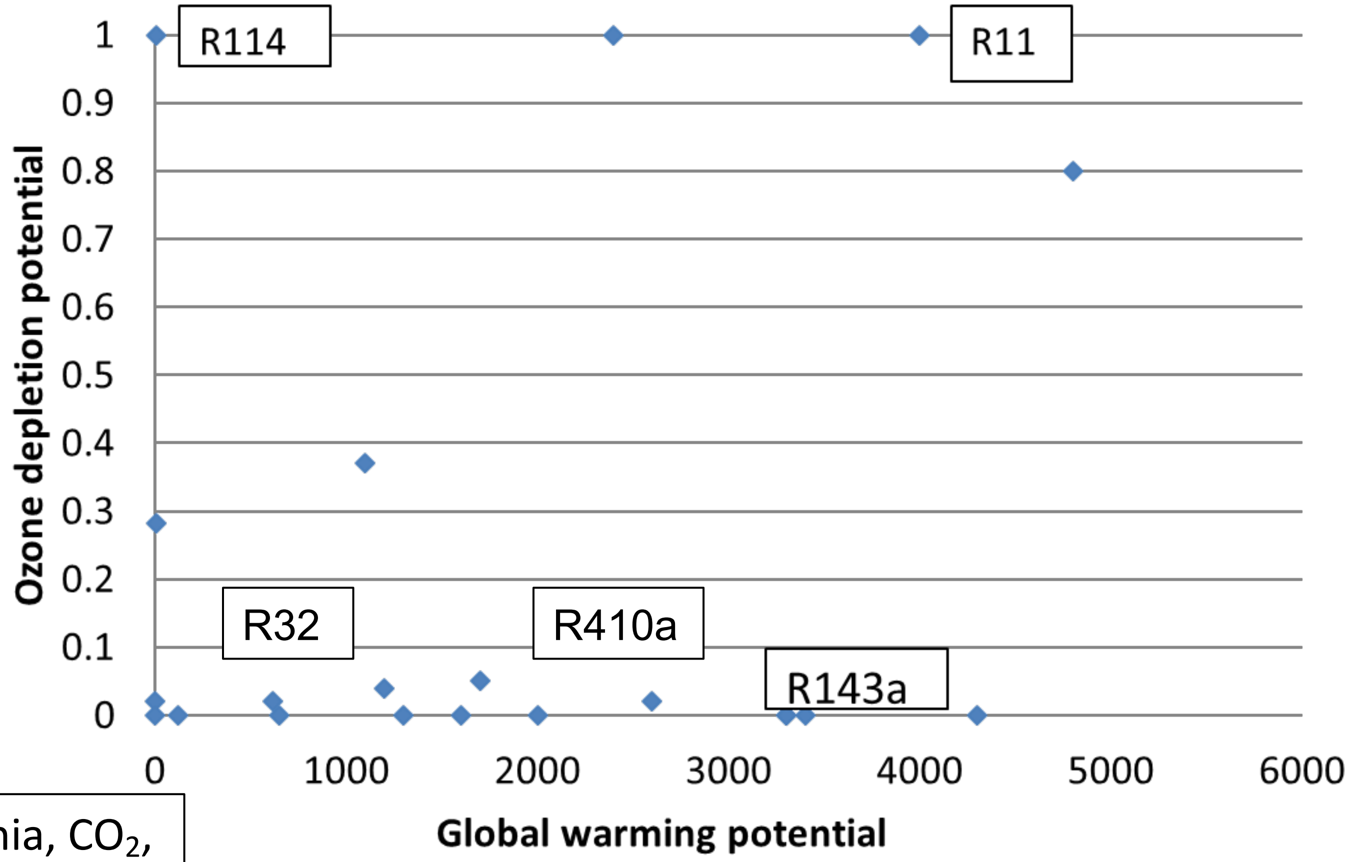
https://www.bregroup.com/heatpumpefficiency/index.jsp

Refrigerants

- Refrigerant choices?

- Zero ODP
- ODP defined in relation to R11=1

- Lower GWP values
- GWP defined in relation to CO_2=1



Ammonia, CO_2, Water, Air

Example 1 - Daikin Altherma (split unit)

- Low energy bungalow
- Solar Thermal DHW + immersion
- Underfloor Heating throughout

Example 2 – 8kW Mitsubishi Ecodan

- Refurbished bungalow, South of Manchester
- Filled with cavity wall insulation, roof & floor insulation
- EPC states 8614kWh/a heating
- Underfloor Heating on ground floor
- £7,520 installation RHI compliant
- £1,500 for 150L DHW cylinder
- Switched electricity supplier
- "Heatmiser" room thermostats
- Efficient wood burning stove.

Example 3 - Daikin Altherma (monobloc)

- Uninsulated stone farmhouse
- Replaced oil fired boiler and hot water cylinder
- Altherma internal unit has integrated DHW
- Buffer tank
- Additional heat from open fireplace

Example 4
New R32, 8.5kW Mitsubishi Ecodan

- Ultraquiet operation
- Small semi-detached, South of Manchester
- Filled with early specimen cavity wall insulation, loft insulation added
- EPC yet to be done
- Wood burning stove
- £12,540 (VAT inc.) for installation
- Have yet to apply for RHI
- Includes bespoke 150L DHW cylinder

6. Install, operate, monitor

Not another 3 word slogan…

Installation

- Install to designer’s outline specification and manufacturer’s instructions
- Installer to confirm any additional system components required for a fully operational system – agree with designer if necessary
- Installer decides on supports – check appropriate
- An experienced and meticulous plumber may be a better fit for monobloc installations – neat is good
- Check insulation around pipes

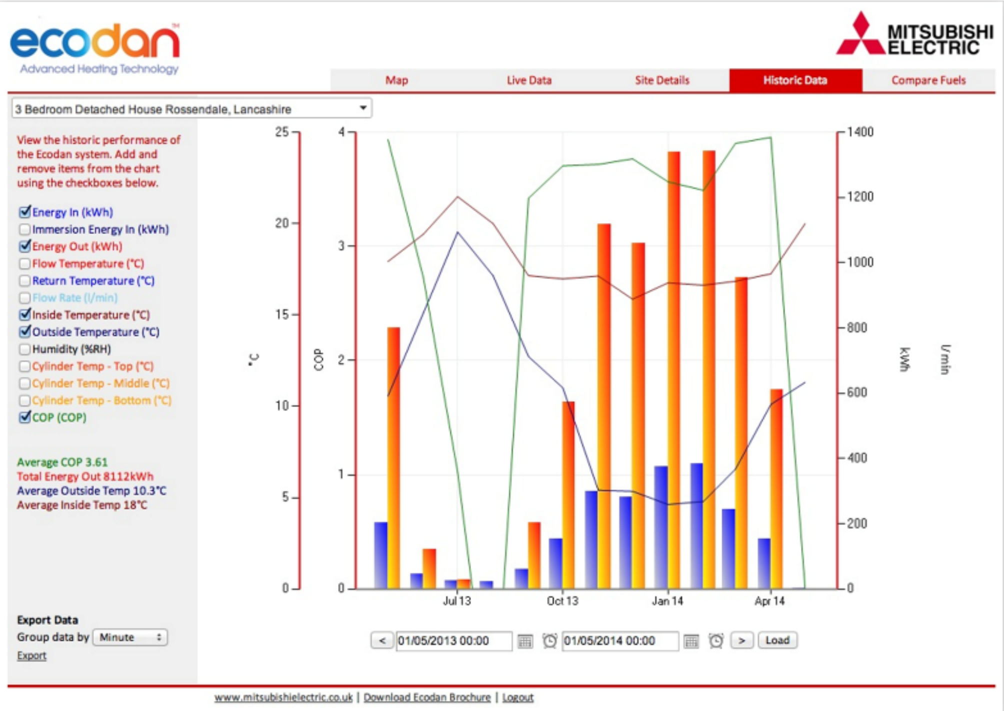
Commissioning

- Confirm sufficient condenser water flow rate to maintain the manufacturer's stated nominal condenser ΔT at maximum output
- Check heating system is fully purged of air
- Check that circuits are properly balanced
- Note the minimum heat emission capacity to which the ASHP may be connected
- Make sure all living and circulation area TRVs are set to max, or in the case of underfloor heating, remove actuators from bathrooms/toilets and circulation areas (unless specified otherwise)
- Check manufacturer-specific checklist for controller settings and make sure they are fully completed.
- Where weather compensation is used, ensure that the settings are not too low so as to cause excessive cycling.
- Set appropriate DHW settings
- Set up the legionella protection plan as per manufacturer's instructions
- Follow-up site visits

Adapted from Superhomes 2.0

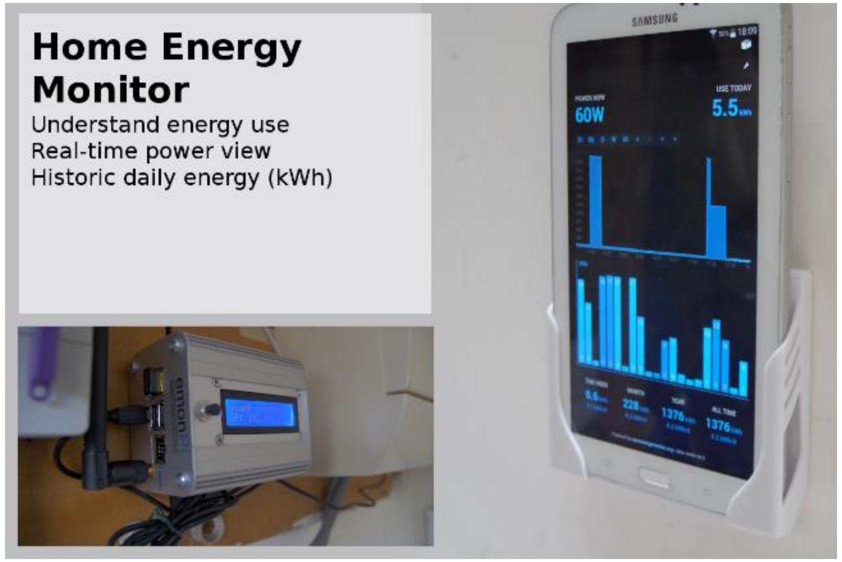
Controls and Monitoring

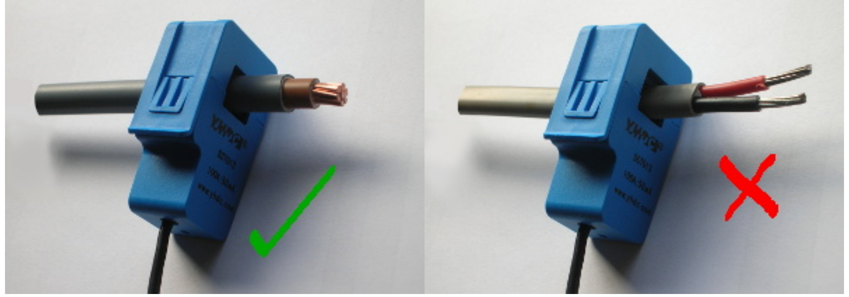
- Thermostat and zone controls – position them correctly
- Can in most cases specify your own – just need to check compatibility if you do
- Weather compensation
- Basic system apps



Monitoring

- Check what is covered by the RHI additional payment.
- It will depend what you find useful (e.g. a simple app you can get a snapshot from, troubleshooting, etc.).
- You can add another system for monitoring to obtain own data such as OpenEnergyMonitoring.





Operations that affect performance

- Compressor Cycling
- Defrost cycle (overall COP and sometimes also delivery temperature)
- Ice build-up
- Over- and under-sizing
- Weather compensation curve (also called Heating Compensation Curve)

Compressor Cycling

- Compressor cycling – number of times the compressor is switched on and off in an hour.
- Reduce CC for higher performance.
- Strategies include: larger inertia (volume of water) in the system – UFH provides this, and large radiator systems but with a limited number of circuits and zones.
- Otherwise a buffer tank will be needed
- Installer can calculate need for buffer based on manufacturer information

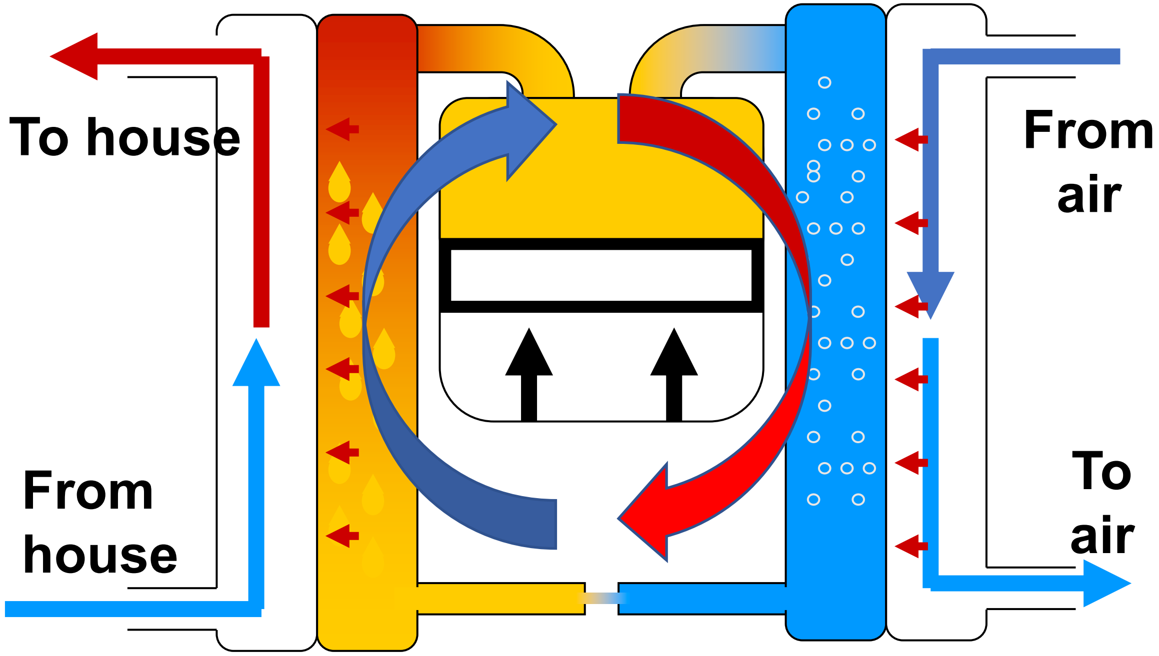
Ice build-up and defrost cycle

At low temperatures frost will build up on the evaporator fins and coil.

Approx. 10% drop in efficiency with ice build-up.

Modern HPs automatically run a defrost cycle: cycle is reversed in order to melt the ice formed on the evaporator (now condenser) coil.

In some cases it may be a good idea to have a buffer to iron those periods out. Many have this built in.



Defrost cycle: the heat pump is run in reverse

What are the 6 things to bear in mind?

1. Not a boiler
2. What do I need to do to my house to make it heat pump-ready?
3. All these components - do I have space? Do I have the budget?
4. I'm going for it, what next? How big? How do I get help? How do I buy it?
5. So many types – what's best for my needs?
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Resources

Resources

John Cantor

"Heat Pumps for the home" by John Cantor, The Crowood Press Ltd., 2011 (about to be updated and reprinted)

www.heatpumps.co.uk

Superhomes 2.0, Best Practice Guide for ASHP Retrofit, Institute of Limerick, March 2019

Enhabit blog post: Is my house suitable for an ASHP?

BRE https://www.bregroup.com/heatpumpefficiency/index.jsp

Carbon Coop webinars – YouTube channel

https://openenergymonitor.org/