iBRoad2EPC

TRAINING MODULE FOR CONSTRUCTION PROFESSIONALS

7 – Heating, cooling, ventilation, and DHW system

This project has received funding from the European Union's HORIZON 2020 research and innovation programme under grant agreement No 101033781

TRAINING MODULE FOR CONSTRUCTION PROFESSIONALS

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under grant agreement Nº 101033781

ULO No	Autonomy and Responsibility	Skills	Knowledge
7	Provide conditions and perform correct installation and exploitation of the building systems (heating, cooling, ventilation, and DHW)	Provide conditions for installation of new building systems or potential replacement of existing ones	Basic principles for providing heating, ventilation, cooling and DHW in buildings and most common issues arising in renovation projects. The link between envelope renovation and the output of heating and cooling systems. The principles of airtightness and insulation of the building systems. The link between envelope and building systems

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Basic principles for efficient heating systems

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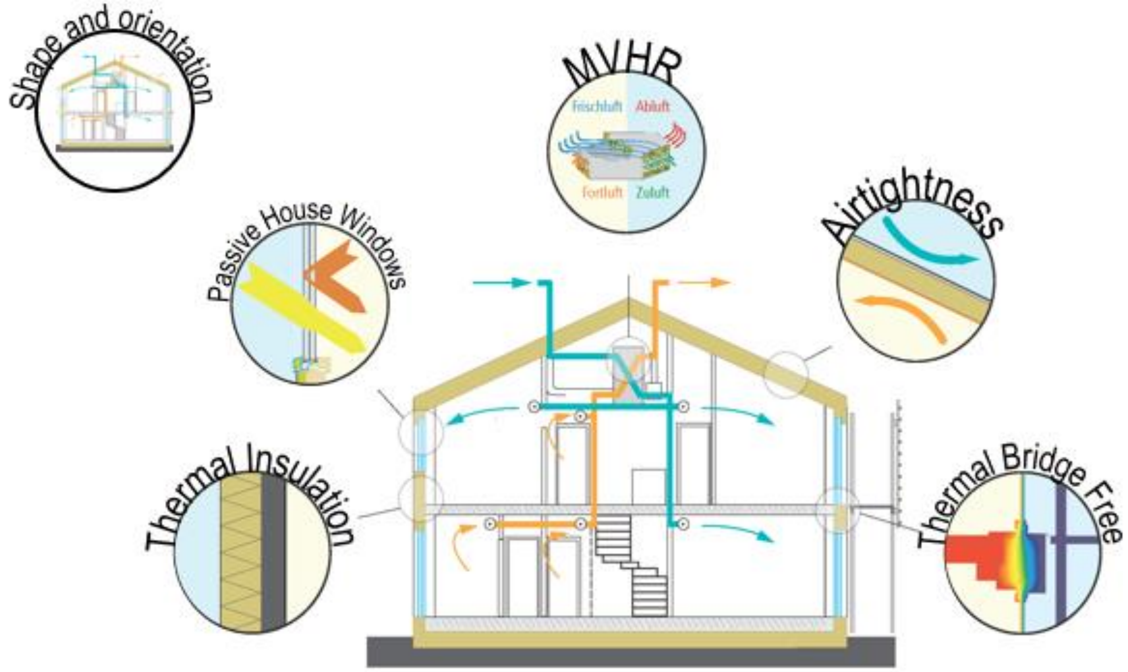
Building quality and HVAC systems

Principles of passive house requires quality in construction

Building envelope with:

1. Thick insulation
2. Tight super insulated windows
3. Thermal bridge free construction or

   TB calculated in energy losses
4. Airtightness



SIGNIFICANT DECREESE OF HEAT LOSSES TROUGH BUILDING ELEMENTS

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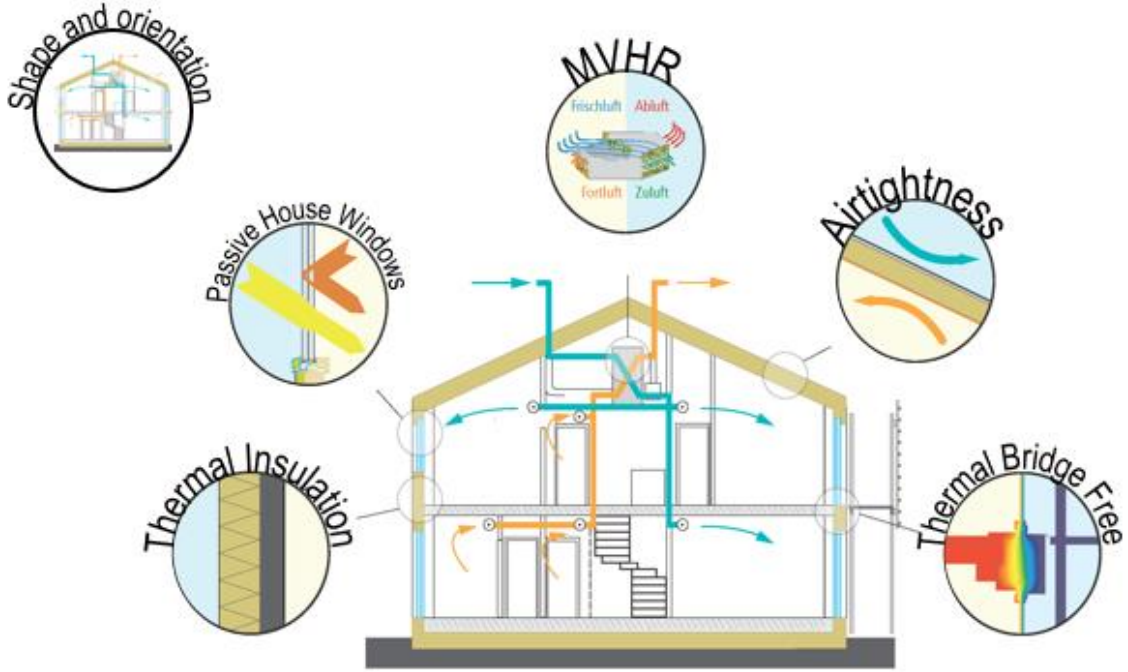
Building quality and HVAC systems

Principles of passive house requires quality in construction

Building systems

1. Mechanical ventilation that eliminates the need of opening windows
2. Heat recovery



NO NEED OF ARTIFICIAL INCREASE OF HEAT LOSSES BECAUSE OF OPENING WINDOWS

TRUSTFUL HEAT LOSSES CALCULATION!!!

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Heating demand

Typical energy needs in passive house

Determine annual "space heat demand"

How much energy is needed each year for heating?

kWh of electricity

Litres of oil

Cubic metres of gas

Kilos of wood

Reference scales:

New-build Passive House standard: **≤ 15 kWh/(m^2·yr)**

Retrofit Passive House standard ('EnerPHit'): **≤ 25 kWh/(m^2·yr)**

Retrofitted to NZEB: **Depends on cost optimization: likely to be ~ ≤ 25 kWh/(m^2·yr)$^{+)}$**

Existing building stock: **Will vary hugely with age of building and climate: ~ 150 kWh/(m^2·yr) $^{+}$**

Assuming 20˚C on a 24-hour basis (see next slide)

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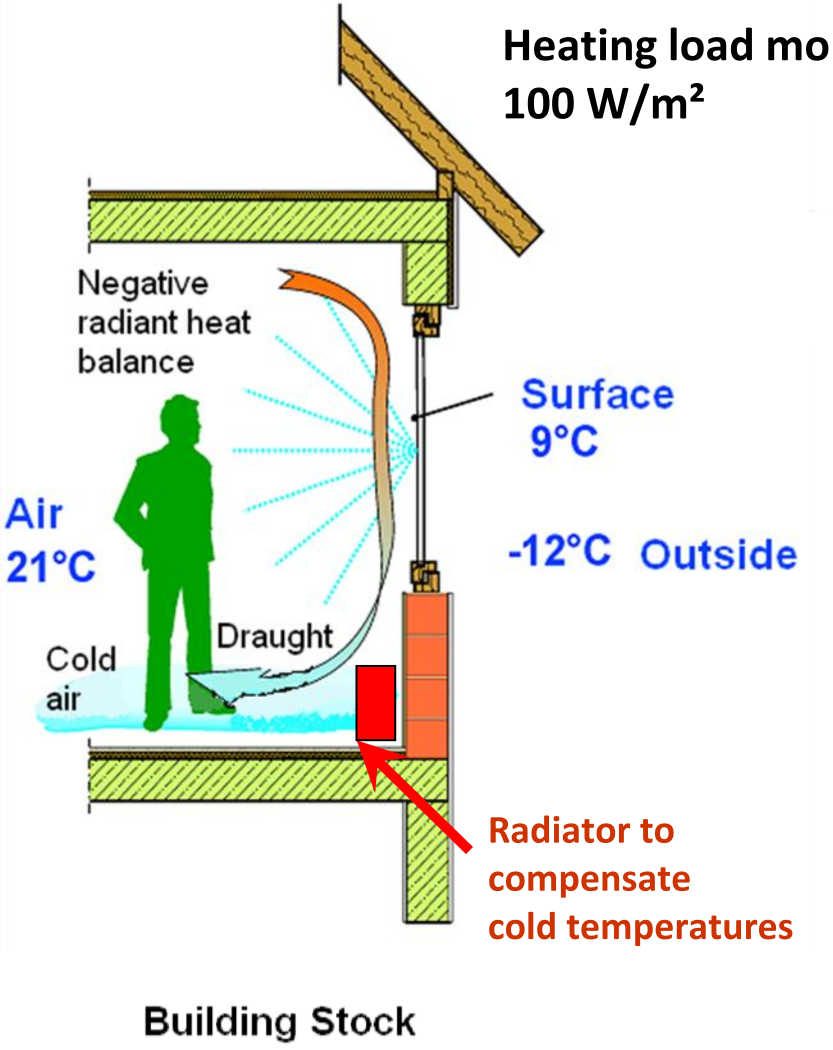
Heating demand

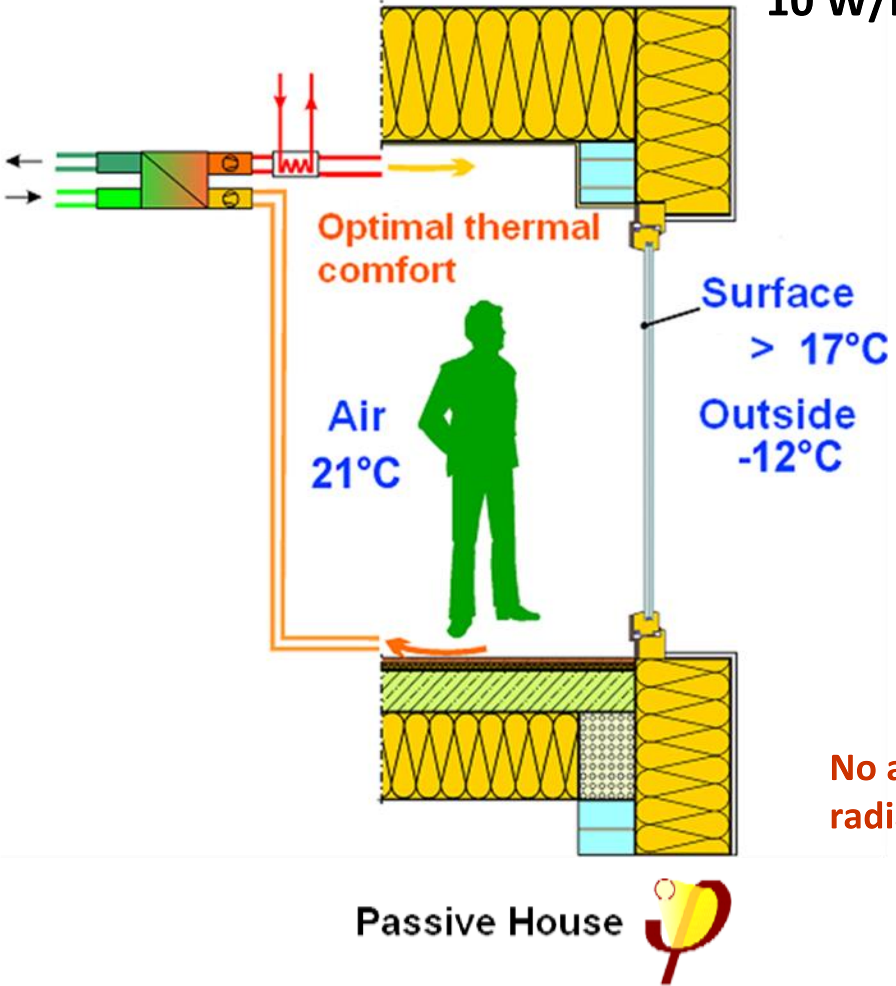
Comfort in passive house/NZEB building

Heating load more than 100 W/m²



Radiator to compensate cold temperatures

Heating load only 10 W/m²



No additional radiators

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Heating demand

Calculating Space Heat Demand

Energy Balancing

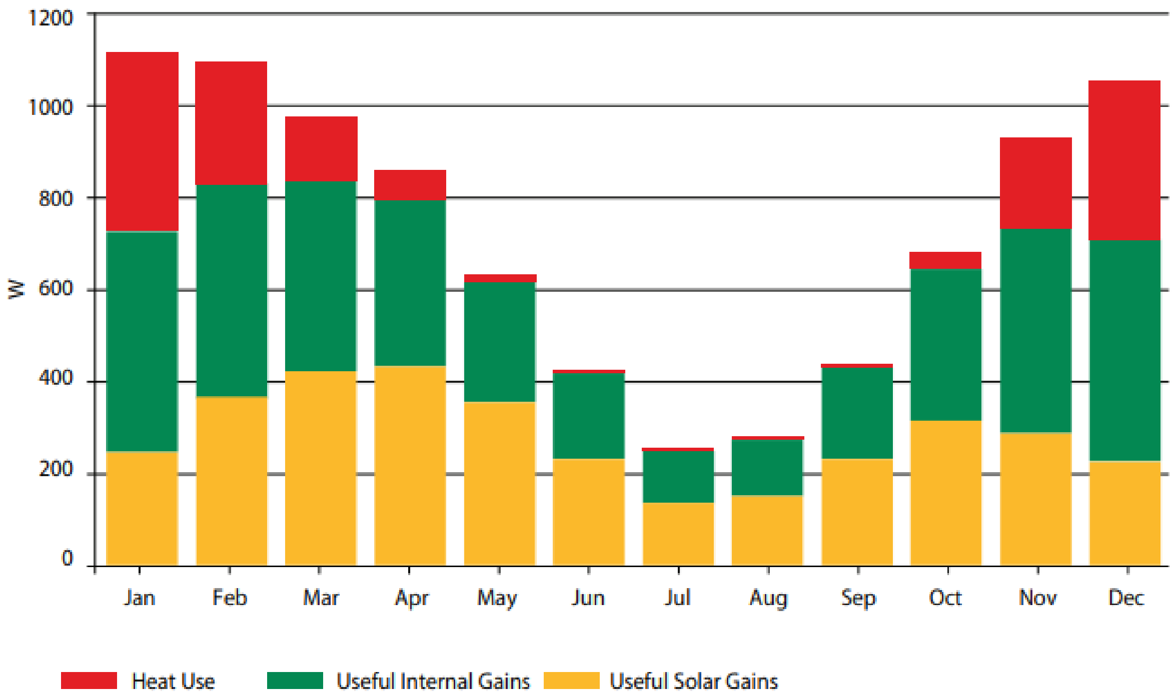
Whilst the precise energy modelling protocols are different, the most of energy modeling tools in Europe and PHPP tools essentially follow the same procedure of carrying out an energy balance calculation.

This energy balance calculation estimates the total heat losses and total heat gains across the year. The ‘heat use’ (as referred to in the adjacent graph) is the difference between these losses and gains.

‘Heat Use’ peaks in winter and is practically zero between May and September

High efficiency domestic dwelling in Ireland

Figure 10: Net space heat demand



Source: Sustainable Energy Authority of Ireland

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Efficiency of heat generation

Heating demand

How does the NZEB energy modelling tool determine annual "space heat demand"

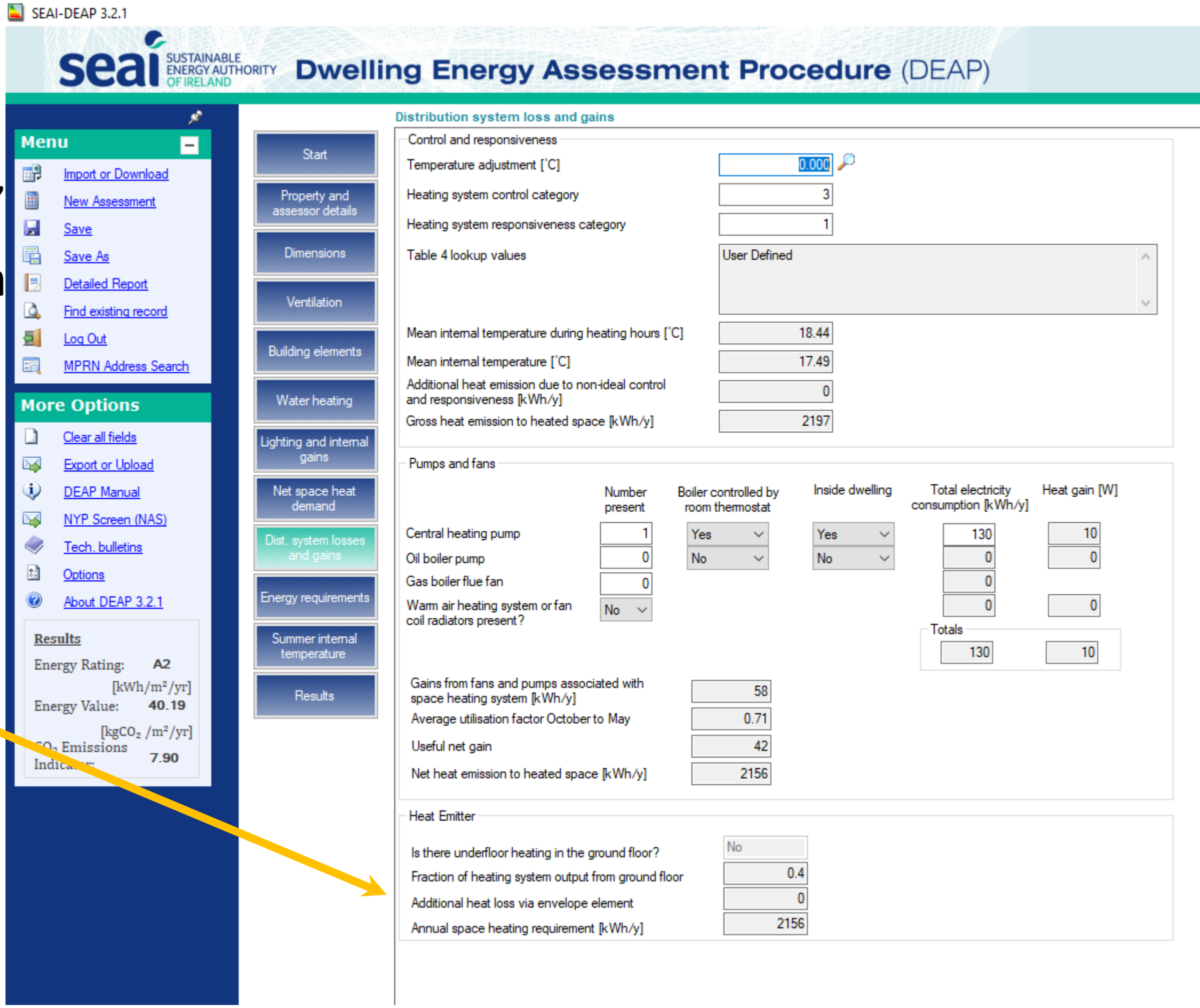
In the Irish tool (DEAP: Dwelling Energy Assessment Procedure), there is an assumption of comfort provision for 2 hours in the morning and 6 hours in the evening (total **8 hours maximum** active 'heating').

This compares with 24 hours comfort in Passive House energy modelling tool PHPP (Passive House Planning Package)

Reference scales:

In this screen shot from the Irish DEAP tool, the annual heating demand for a new-build dwelling is 2,156 kWh/year.

This calculation is based on a DEAP heating degree days of 22 kKh/m2.year. The PHPP tool for the same location uses a value of 66 kKh/m2.year.



Results

Energy Rating: A2

Energy Value: 40.19 [kWh/m²/yr]

CO_2 Emissions Indicator: 7.90 [kgCO₂ /m²/yr]

Distribution system loss and gains

Control and responsiveness

Temperature adjustment ['C]	0.000
Heating system control category	3
Heating system responsiveness category	1
Table 4 lookup values	User Defined
Mean internal temperature during heating hours ['C]	18.44
Mean internal temperature ['C]	17.49
Additional heat emission due to non-ideal control and responsiveness [kWh/y]	0
Gross heat emission to heated space [kWh/y]	2197

Pumps and fans

	Number present	Boiler controlled by room thermostat	Inside dwelling	Total electricity consumption [kWh/y]	Heat gain [W]
Central heating pump	1	Yes	Yes	130	10
Oil boiler pump	0	No	No	0	0
Gas boiler flue fan	0			0	
Warm air heating system or fan coil radiators present?	No			0	0
Totals				130	10

Gains from fans and pumps associated with space heating system [kWh/y]	58
Average utilisation factor October to May	0.71
Useful net gain	42
Net heat emission to heated space [kWh/y]	2156

Heat Emitter

Is there underfloor heating in the ground floor?	No
Fraction of heating system output from ground floor	0.4
Additional heat loss via envelope element	0
Annual space heating requirement [kWh/y]	2156

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Efficiency of heat generation

Heating demand

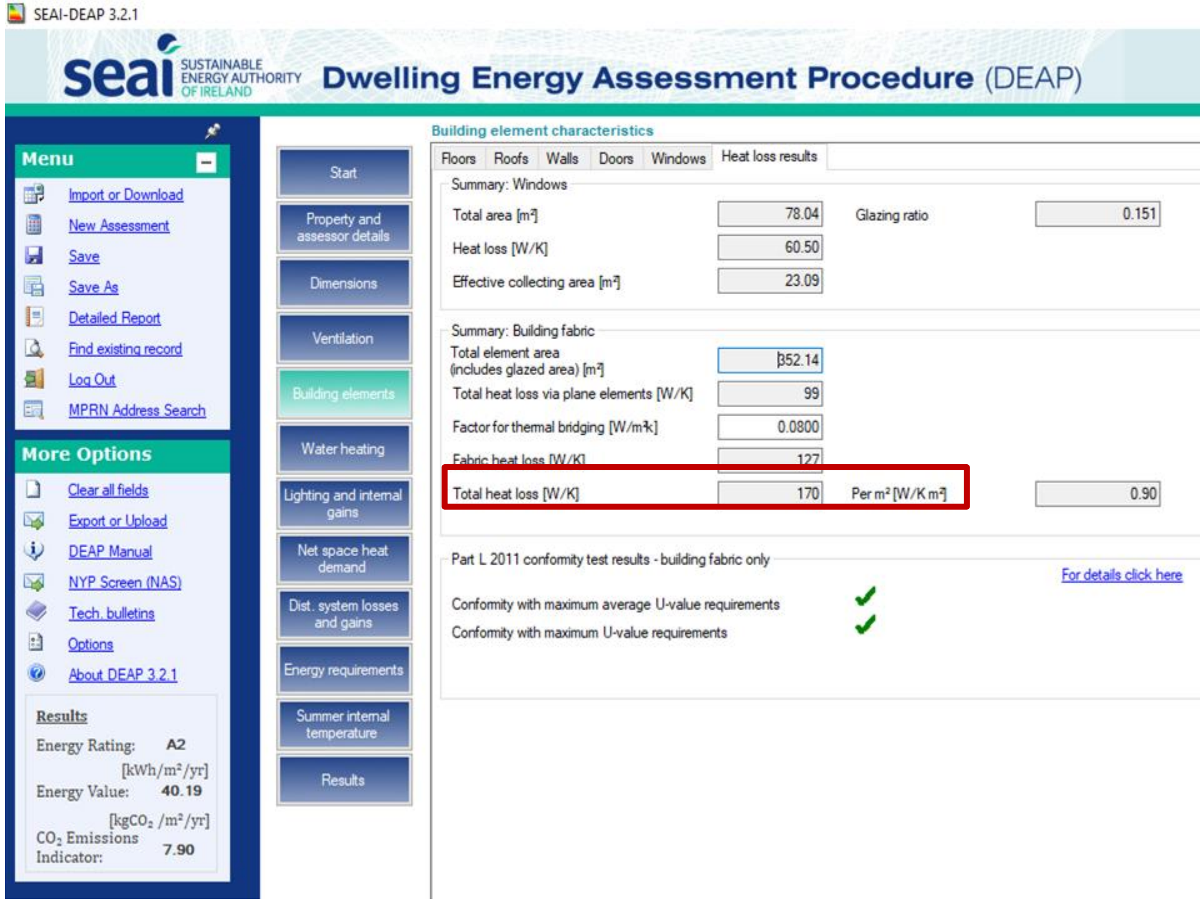
Determine the “heating load”

How much heating power in Watts or kilowatts is needed to provide comfort?

Reference scales:

- New-build Passive House standard:
  ≤ 10 W/m²
- Retrofit Passive House standard (‘EnerPHit’):
  ~ 15 to 20 W/m²
- Retrofitted to NZEB:
  Vary with cost optimization: ~ 15 to 20 W/m²+
- Existing building stock:
  Will vary with age and climate: ~ 100 W/m² +

In the screen-grab across, the Irish DEAP tool calculated (for a new build project) a total heat loss of 170 W/K.
As a rule of thumb, in Ireland a delta T of 26˚K is used, totaling 170 W/K X 26˚K = 4,420 W heat load



Building element characteristics

Summary: Windows

Total area [m²] 78.04
Glazing ratio 0.151
Heat loss [W/K] 60.50
Effective collecting area [m²] 23.09

Summary: Building fabric

Total element area (includes glazed area) [m²] 352.14
Total heat loss via plane elements [W/K] 99
Factor for thermal bridging [W/m²k] 0.0800
Fabric heat loss [W/K] 127
Total heat loss [W/K] 170
Per m² [W/K m²] 0.90

Part L 2011 conformity test results - building fabric only

Conformity with maximum average U-value requirements ✓
Conformity with maximum U-value requirements ✓

Results

Energy Rating: A2
Energy Value: 40.19 [kWh/m²/yr]
CO_2 Emissions Indicator: 7.90 [kgCO_2 /m²/yr]

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Energy Recovery Ventilation

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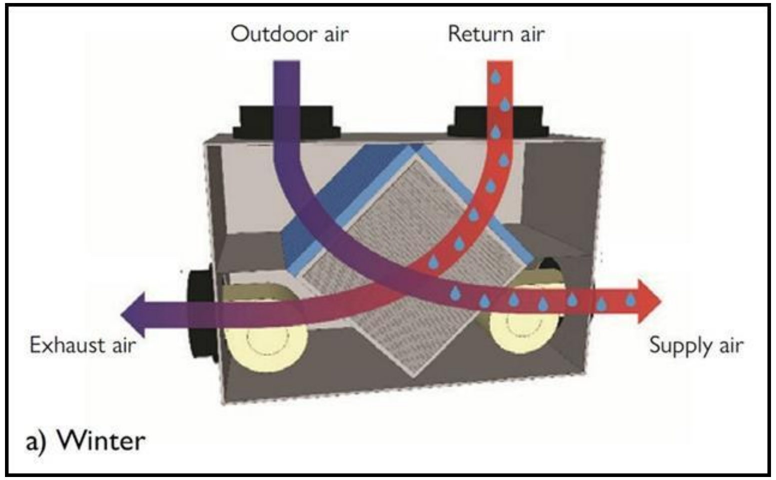
Energy Recovery Ventilation

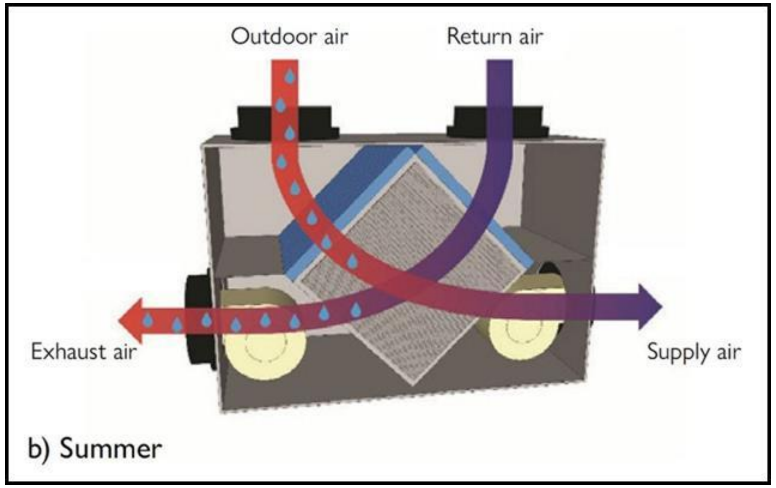
Energy recovery ventilation systems provide a controlled way of ventilating a home while minimising energy loss. They reduce the costs of heating ventilated air in the winter by transferring heat from the warm inside exhaust air to the fresh (but cold) outside supply air. In the summer, the inside air cools the warmer supply air to reduce cooling costs.

There are two types of energy recovery systems: Energy Recovery Ventilators (ERVs) and Heat Recovery Ventilators (HRVs). Both types include a heat exchanger, one or more fans to push air through the machine and controls. There are some small wall- or window-mounted models, but the majority are central, whole-house ventilation systems with their own duct system or shared ductwork.

"Whole-House Ventilation," U.S. Department of Energy (DOE), Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation.



a) Winter



b) Summer

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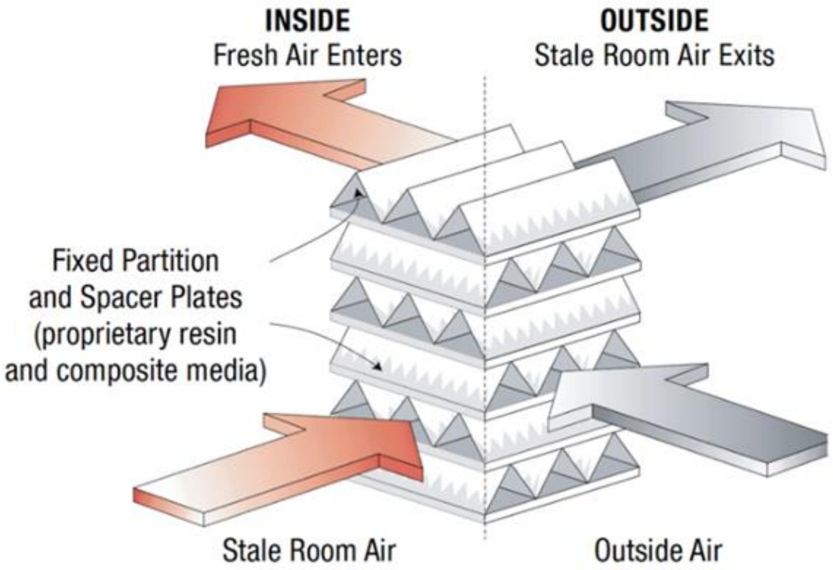
Energy Recovery Ventilation

The main difference between an ERV and an HRV is the way the heat exchanger works. With an ERV, the heat exchanger transfers a certain amount of water vapour (latent) along with heat energy (sensible), while an HRV only transfers heat.

Because an ERV transfers some of the moisture from the exhaust air to the usually less humid incoming winter air, the humidity of the house air stays more constant.
This also keeps the heat exchanger core warmer, minimising problems with freezing.
In the summer, an ERV may help to control humidity in the house by transferring some of the water vapor in the incoming air to the theoretically drier air that is leaving the house. If an air conditioner is used, an ERV generally offers better humidity control than an HRV.

Most energy recovery ventilation systems can recover about 70-80% of the energy in the exhaust airstream and deliver that energy to the incoming air for conditioning purposes.

"Whole-House Ventilation," U.S. Department of Energy (DOE), Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation.



Static-Plate, Enthalpy-Core ERV (Stock Photo)

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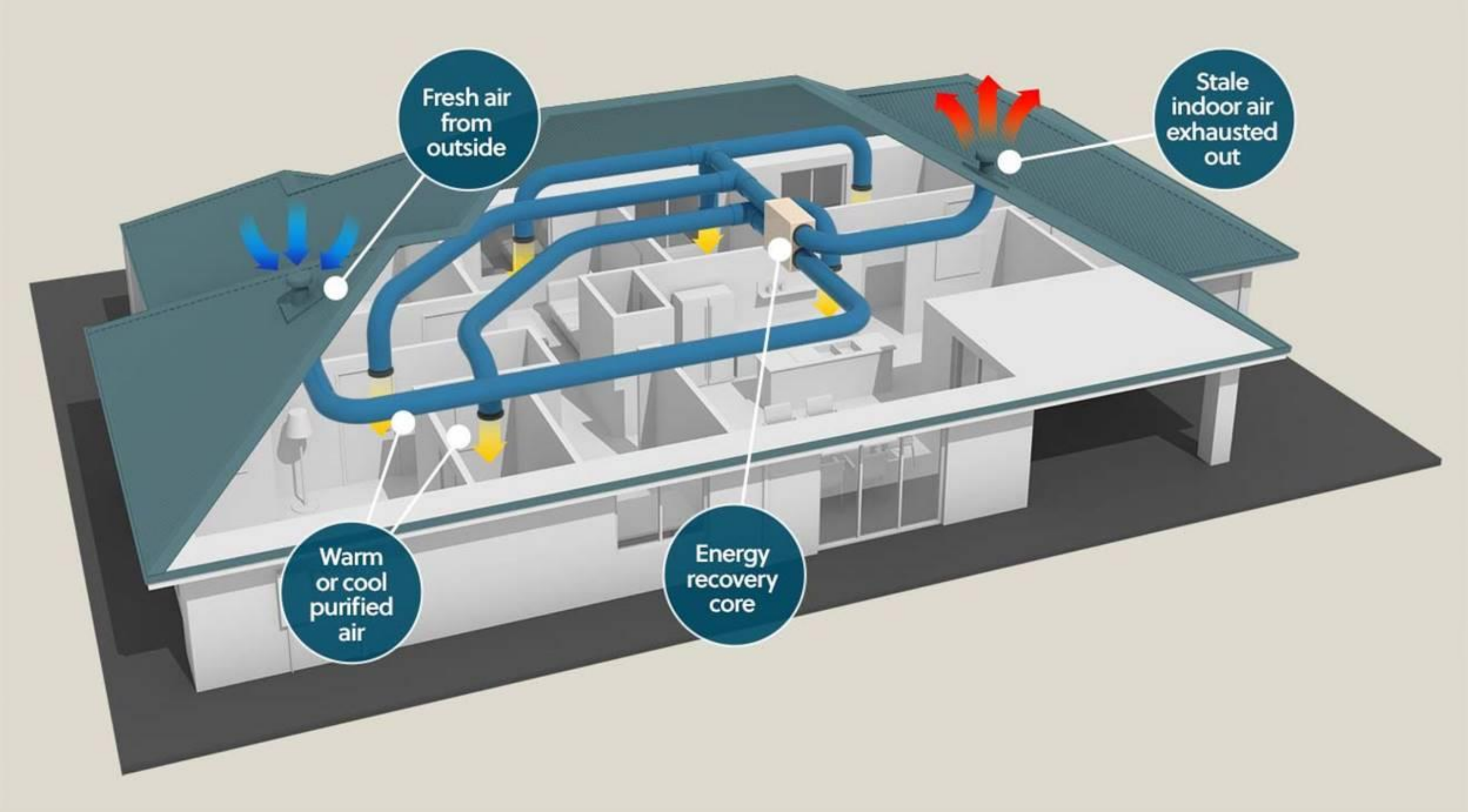
Energy Recovery Ventilation



"Whole-House Ventilation," U.S. Department of Energy (DOE), Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation.

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Mechanical Ventilation with Heat Recovery (MVHR)

MVHR is considered the "lungs" of a highly efficient deep-retrofit ventilation system

Photo: Zehnder

MVHRs must be:

- Super-insulated
- Airtight
- Thermal bridge free
- Compact
- Quiet
- Energy efficient
- Suitably located

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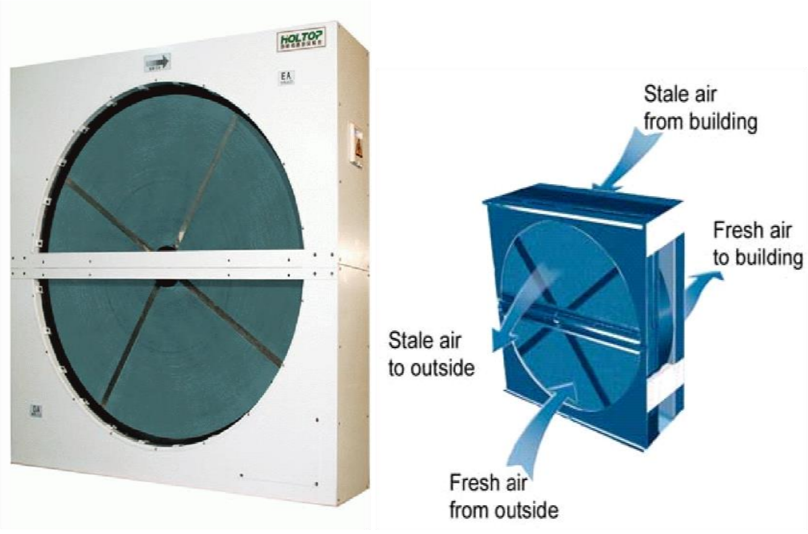
Mechanical Ventilation with Heat Recovery (MVHR)

Rotary heat exchangers

They are made up of a heat recovery material that rotates slowly at a speed of between 5-10 revolutions/min. The air flows pass in the same plane but in different directions: fresh and stale.

The accumulator material is made of a thin foil (usually made of aluminum) with fine corrugations, molded in the form of a cylinder, obtaining a honeycomb with fine channels with an equivalent hydraulic diameter of the order of 1.5 mm. The material is treated hygroscopically and thanks to this it can recover both perceptible and latent heat. This is achieved by successive phenomena of absorption - resorption.

The exchange efficiency varies with the air speed and with the loss of load and speed between 70 - 90%.



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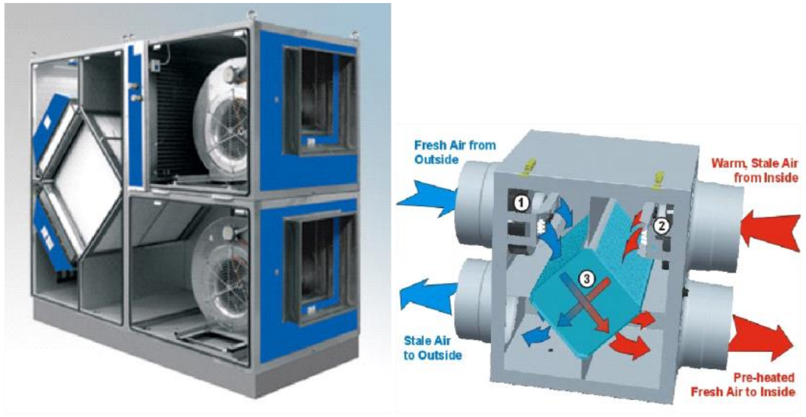
Mechanical Ventilation with Heat Recovery (MVHR)

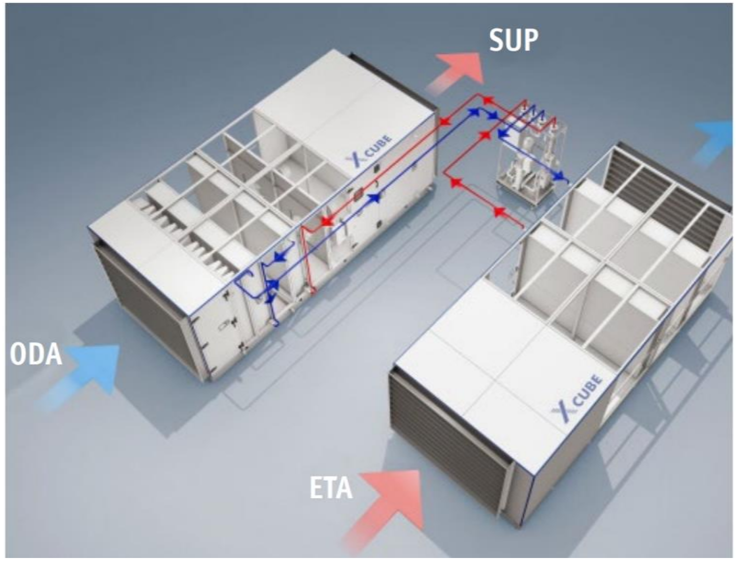
Plate heat exchangers

The air currents are separated by means of steel, aluminum or plastic plates arranged in parallel at a short distance. The air crosses the plates against the current or in parallel and there is no contact whatsoever between the fresh air and the exhaust air. This type of recuperator is a surface exchanger. Inside, only a perceptible heat exchange usually takes place. The plates are provided with corrugations arranged in advance or not located at distances of 2 - 10mmm. The exchange yield is between 60 - 70%.



Heat exchangers with intermediate thermal fluids

They consist of two battery-type heat exchangers with fins located in the channels of fresh air and exhaust air. An intermediate fluid circulates between the two batteries that takes heat from the exhaust air and transfers it to fresh air. This type of construction allows the introduction of a three-way valve and therefore the possibility of automated adjustment. The three-way valve allows to limit the amount of heat recovered which is useful during transition periods. The exchange efficiency is about 60% and is recommended only if fresh air is used without mixing with recirculated air.



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Ventilation Controls

- At least **3 speeds**:

1. **Setback:**

   At least 30% less than standard

2. **Standard:**

   Outdoor air requirement according to standard occupancy

3. **Boost:**

   At least 30% more than standard, usually activated by a separate switch, and timer-based so it returns to normal after defined period

Source: Zehnder

Note:
Be aware that heat recovery efficiency will decrease with increasing flow rates (less 'time' for the heat to exchange as air passes through the core)

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Ventilation Controls

- In addition to ventilation rates, most control systems will offer the following:
- **Summer Bypass**
  - Temperature-only or enthalpy (heat + humidity) based
- **Balancing / Commissioning**
  - Fine-tune fan speeds for exact air flow rates
- **Scheduled operation**
  - Example, filter change warning light
- **Error indicators**

Note:

Balancing of system is normally achieved by adjusting (closing or opening slightly) supply and extract grills

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Combination heating/cooling and MVHR

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Heating via ventilation

Concepts for heat distribution

Residential buildings

With less than 15 W/m^2 can be heated with ventilation system in most of the cases

Requirements:

- Inlet temperature to be less than 52 °C
- All the rooms to be part of ventilated volume
- Precisely control of the air heater

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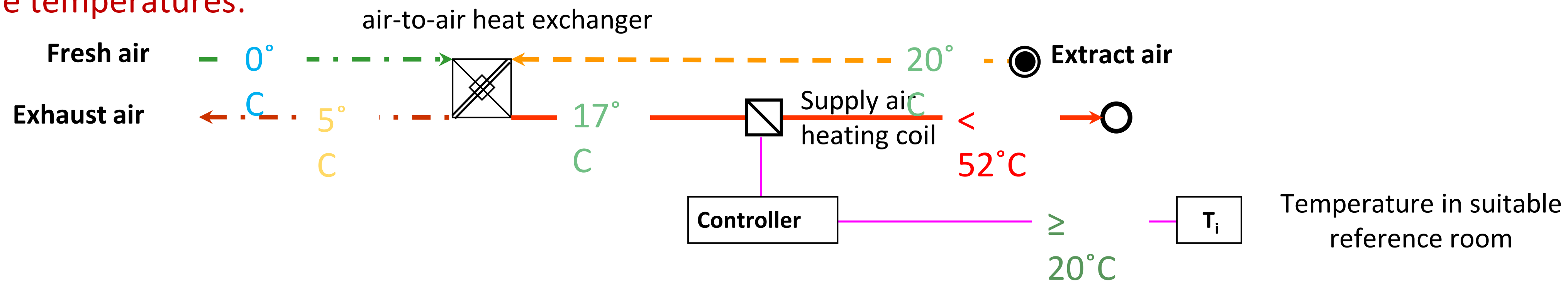
Heating via ventilation

Classic Passive House: Supply Air Heating

Example temperatures:



Features and requirements:

Maximum supply air temperature after heating coil is 52°C, otherwise dust smolders

Max heating load approximately 10 W/m² (based on ventilation rate, typical occupancy density, and peak supply temp of 52°C)

- If the air flow rate is increased above fresh air requirements (30 m³/h per person at boost rate), the **air might get too dry in winter**
- In **single-family houses one central heating coil** is sufficient; temperature sensors should be installed in a suitable reference room
- **Multi-family buildings: Separate heating coils** for each apartment

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Heating via ventilation

Next Generation Compact HP Unit

‘Combo-systems’ emerging on the market tha provide the following functions:

Heating

Cooling

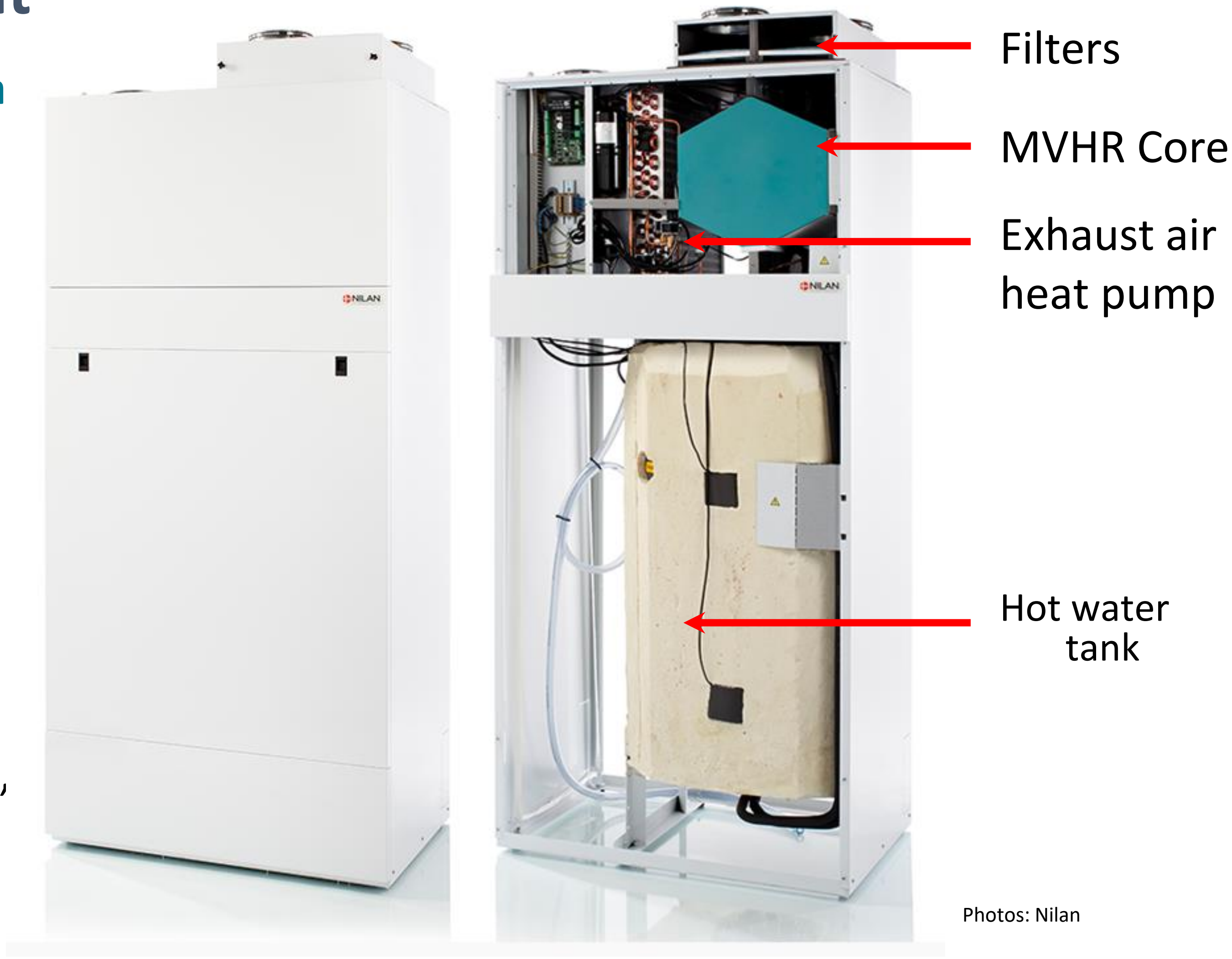
Domestic hot water

Mechanical ventilation with heat recovery

Warning!

Contribution towards heating, cooling and hot water must be confirmed in an energy model such as PHPP

In Passive House projects in Ireland, these systems typically provide 50% of the heat load, with the remainder provided by radiators



Photos: Nilan

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Heating via ventilation

Space Heating and Hot Water Controls

The aim should be to provide the following minimum level of control:

Automatic control of space heating based on room temperature

Automatic control of heat input to stored hot water based on stored water temperature

Separate and independent automatic time control of space heating and hot water

Shut down of boiler or other heat source when there is no demand for either space or water heating from that source

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MVHR with heating system

Multifamily system combinations

Centralised

Pros: More efficient heat recovery; less powerful fe

less expensive

Cons: A prerequisite for neighbour issues in the

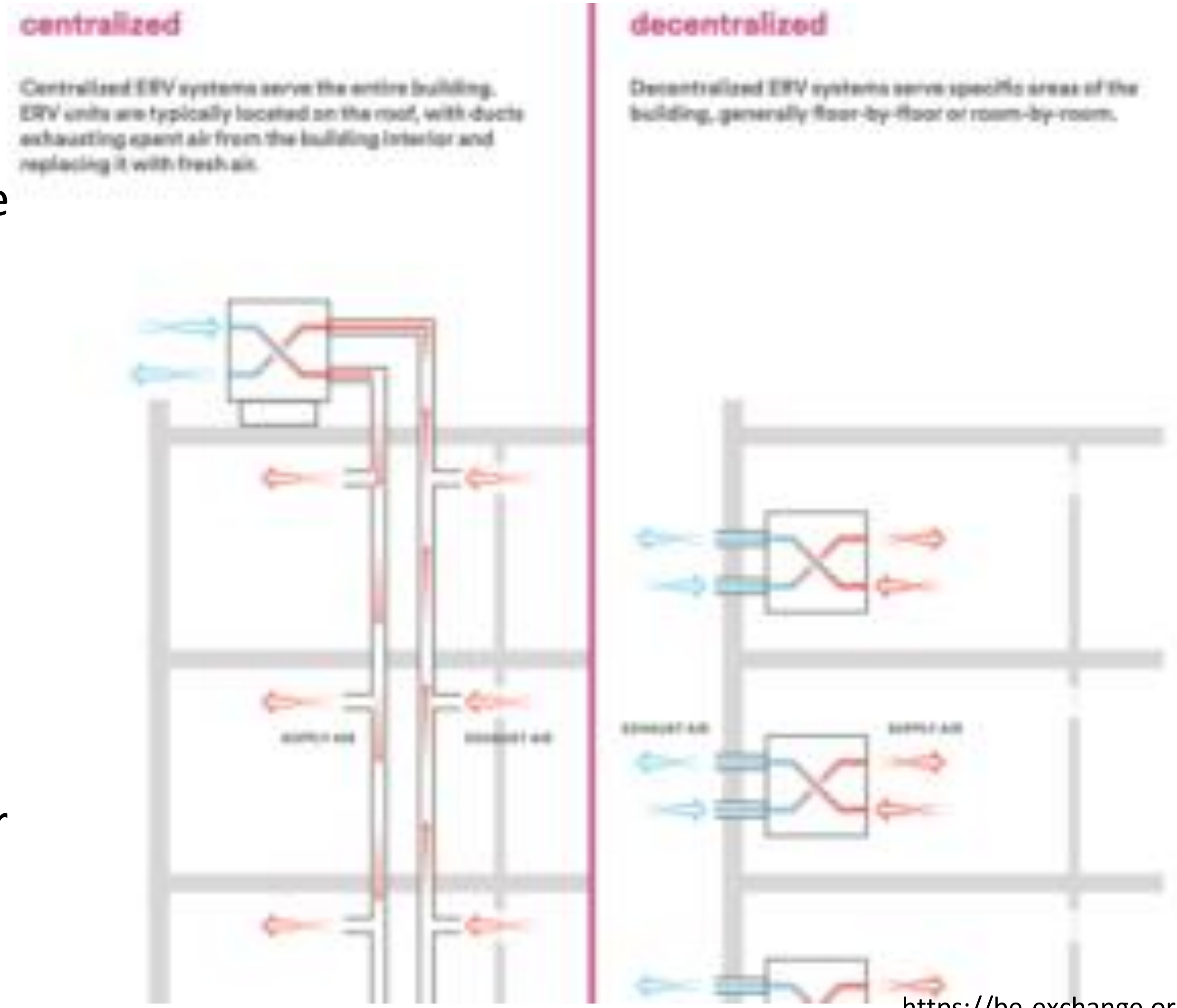
building, especially in co-ownership; Still additional

module for every single apartment is needed

Decentralised

Pros: Every apartment has its own control and ener

bills



centralized

Centralized ERV systems serve the entire building. ERV units are typically located on the roof, with ducts exhausting spent air from the building interior and replacing it with fresh air.

decentralized

Decentralized ERV systems serve specific areas of the building, generally floor-by-floor or room-by-room.

https://be-exchange.org

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MVHR

Other building types

Ventilation units

Typically, single room ventilation

Heat recovery in the classroom

Noise should be considered

Source: https://www.proidea.ro/

Source: https://www.aerismos.gr/

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MVHR

Other building types

Benefits

Better hygiene

Better health (reduced viruses and bacteria)

Better learning results

Less exhaustion and nervousness in students

Fewer missed days at classroom

Source: https://www.kraaijvanger.nl/

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Highly efficient DHW production and heat recovery

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Domestic Hot Water

Demand

- **Space heating demand for NZEB Retrofit** = ~ 25 kWh/m^2.year$^+$

- **Domestic hot water demand** = **18 – 35 kWh/m^2.year**

- Depending on the following:
  - Occupancy (number of people in the house)
  - Solar thermal contribution
  - Use of drainwater waste recovery system

Final energy for hot water:

- Reducing the use of hot water is largely dependent on **occupants**
- An **efficient water heater and distribution system** can make a big difference on the total energy used by reducing unnecessary losses.
- Also think about **water efficient taps, showerheads and appliances**

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Domestic Hot Water

Efficient Design principles

Same basic principle as space heating:

Efficient generation

Use short and well-insulated pipe lengths, especially outside the thermal envelope (best to avoid entirely)

Clustering bathrooms & kitchens can greatly reduce pipe lengths

DHW Generation Options:

Boiler – sealed combustion / direct vent is a must for indoor air quality and building air tightness requirements

External heat pump – temperature top-up will be needed for hygienic reasons

Electric heat pump tank – watch air volume requirements & space temperature reductions, also noise

Solar thermal, or solar photovoltaic + heat pump tank

Electric resistance (tank or tankless) is “efficient” but has high PE impacts.

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Domestic Hot Water

Legionella Prevention

Same basic principle as space heating:

- **Bacteria** commonly found in water – multiplies between 20OC and 45OC
- **Potentially fatal** type of pneumonia – inhaling airborne water droplets
- Primary method of prevention is water **temperature control** (store water at 60OC + and distribute at 50^{O}C with mixer valve to prevent scald)
- Heat pumps typically do not heat water high enough to prevent Legionella, so supplementary resistance electric heat is usually needed
- **Stagnant water** favours Legionella growth – flush out infrequently used outlets (example, in holiday homes)
- Other methods of control include **ionisation and biocide treatments** (example, chlorine dioxide)

* Source: NY Post, 01.07.2015

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Domestic hot water

Consumption - What it depends on?

Heat losses - pipes

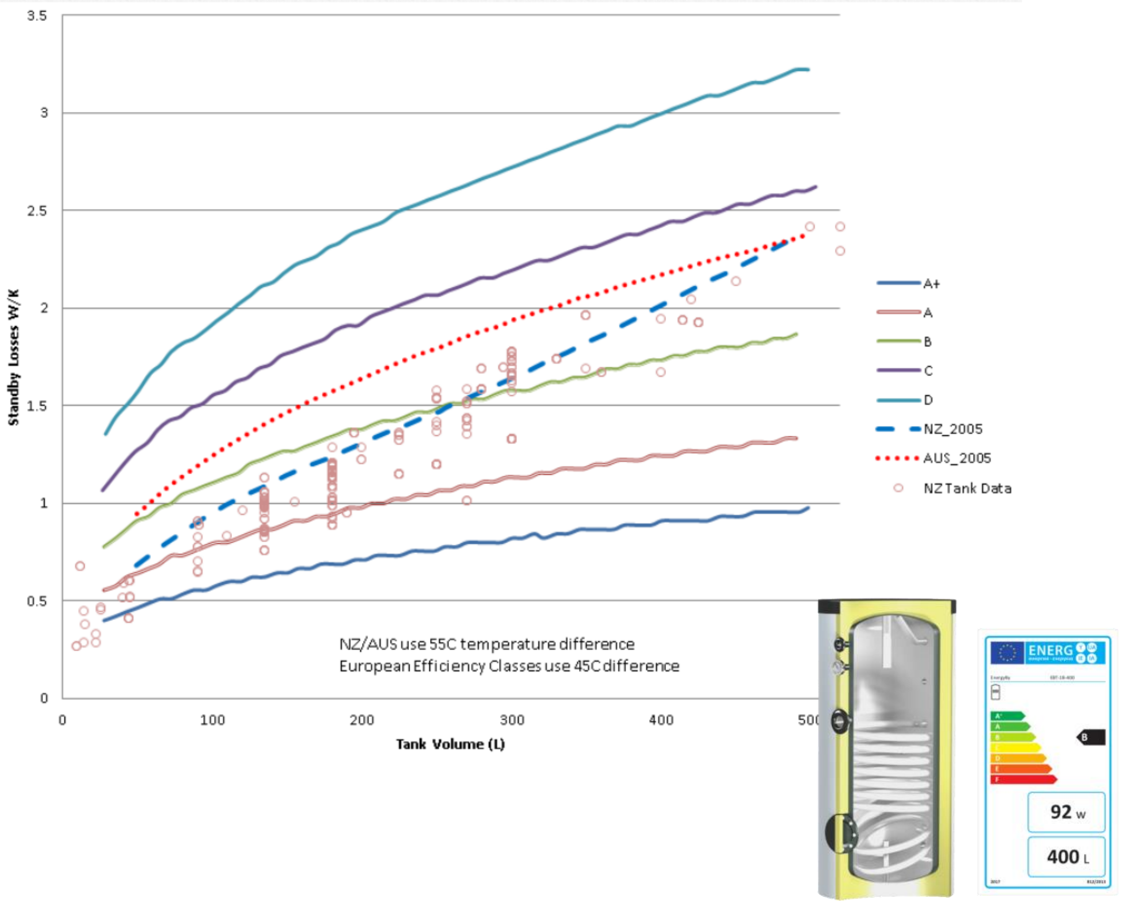
Losses in pipes can be significant, especially in combination with recirculation

Heat losses - water tanks

0.5-3 W/K heat losses depending on size and efficiency

Instantaneous water heaters – pros and cons

Pros	Cons
Reduction of heat losses	High power is needed
No need of waiting in turning the system on	Can't be use as heat accumulation
	incompatibility with most RES



https://sustainableengineering.co.nz/

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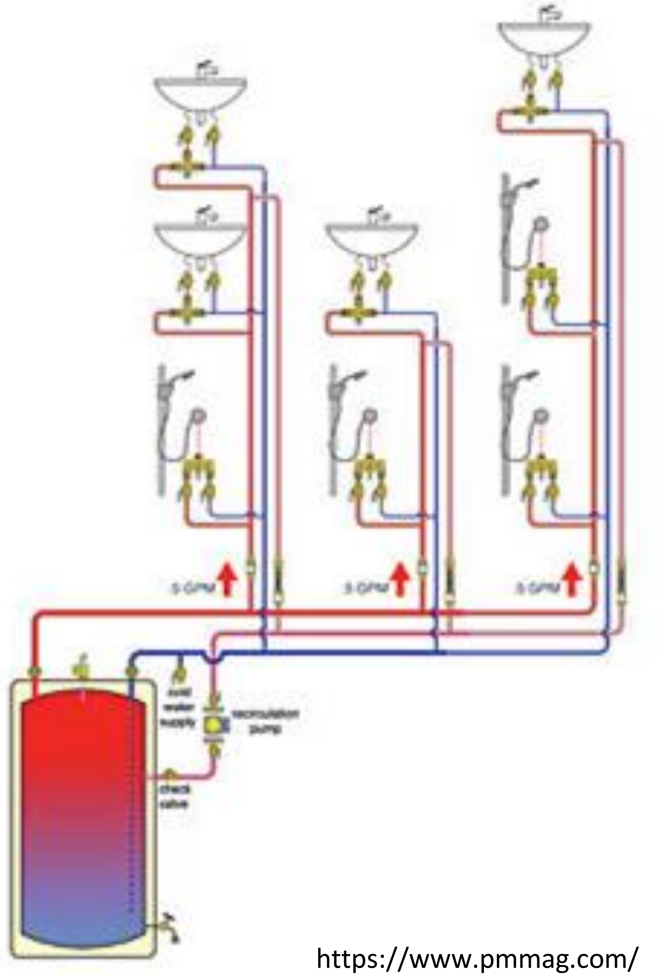
Domestic Hot Water

DHW Circulation Design principles

DHW Distribution:

- Insulating DHW pipes is especially important as only part of the losses can be used, even inside the thermal envelope.
- Insulation thickness should be at least twice the nominal diameter.
- Use smallest diameter pipe possible – shorter wait times, less energy wasted.
- Select efficient circulation / pressurised systems
- Keep pipes as short as possible



https://www.pmmag.com/

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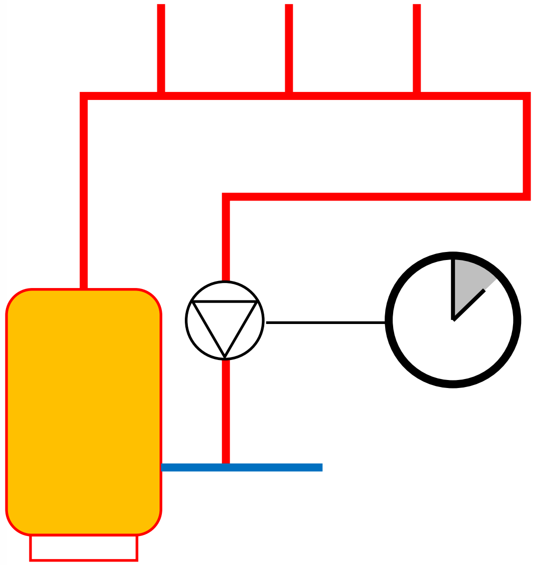
Domestic Hot Water

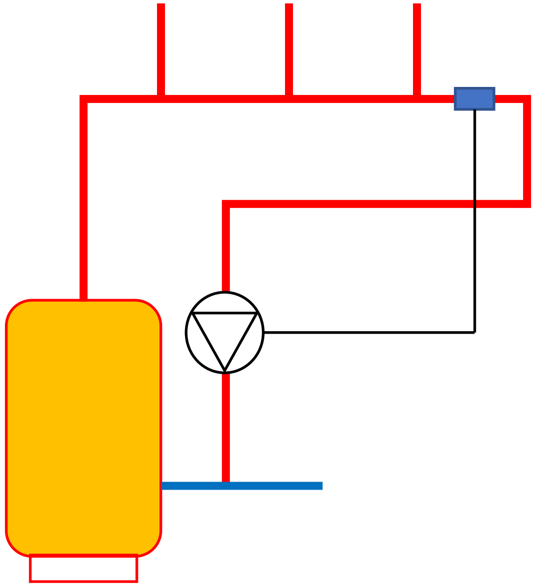
Hot water circulation control – basic options

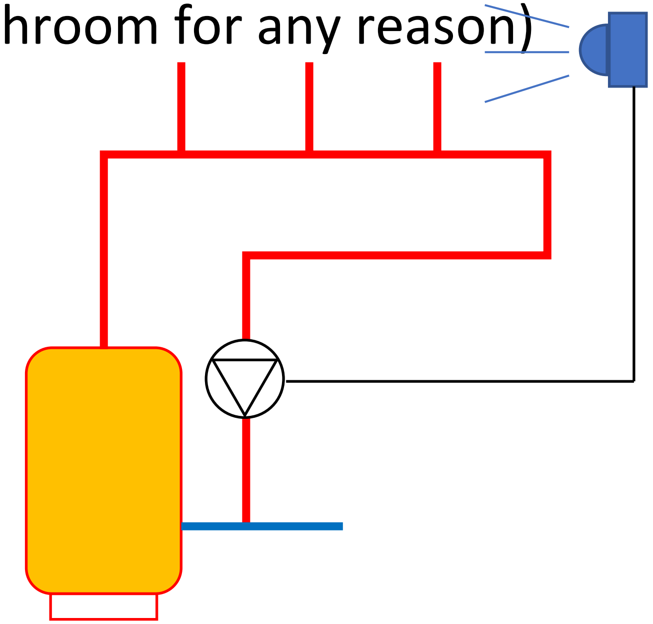
Clock/schedule: recirc pump runs based on timer. Ok for households on regular schedules, if timing is kept tight (i.e. only 1-2 hrs/day)

Aquastat: recirc pump runs based on temperature in pipe. Among least efficient options, as pipes are kept hot

Motion sensor: starts recirc pump whenever motion is detected. Variable efficiency – often triggered by non-DHW events (simply entering bathroom for any reason)







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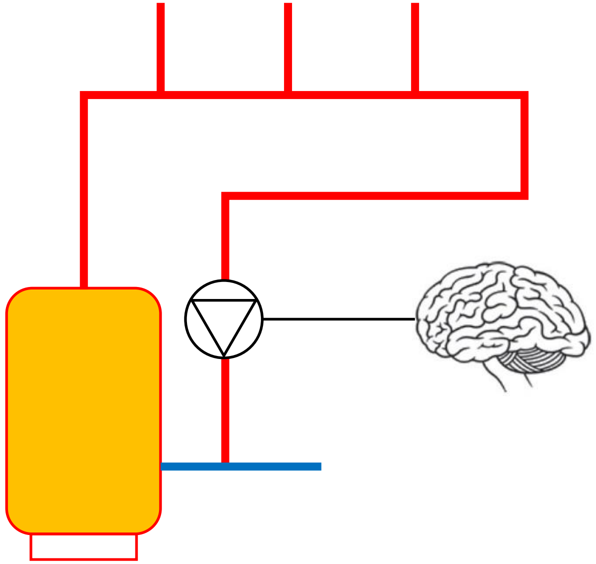
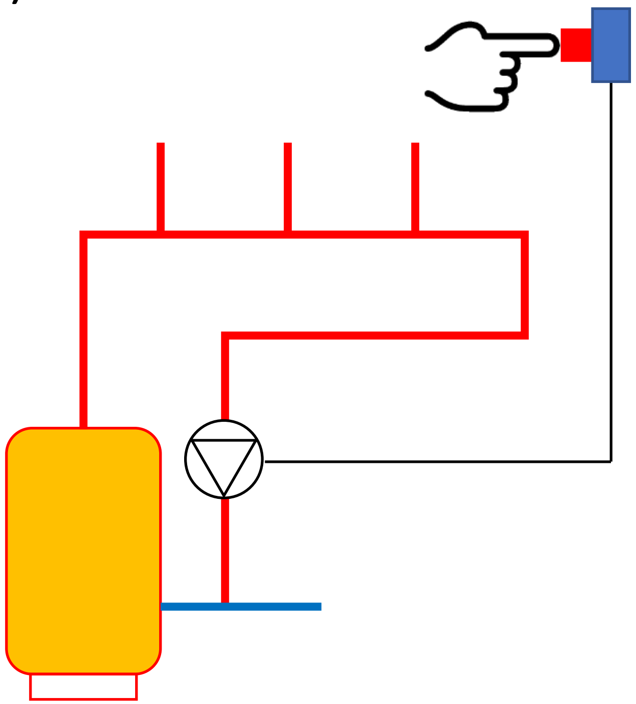
Domestic Hot Water

Circulation control – mid-range options

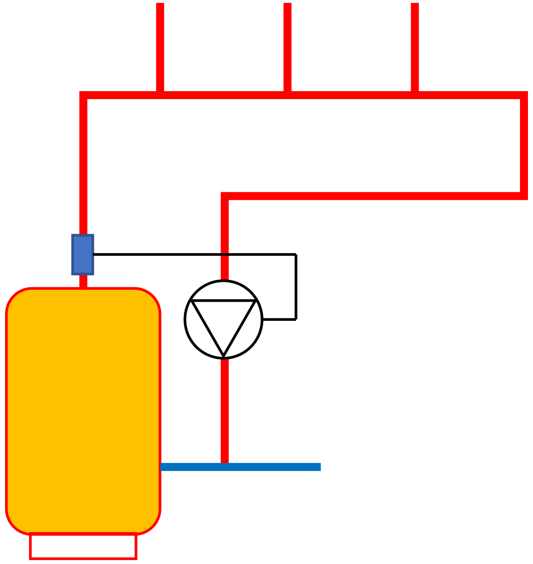
Smart pumps: pump ‘learns’ draw patterns, predicts next draw and runs just before anticipated demand.



Pushbutton: starts recirc pump on occupant demand. Most efficient but may be least convenient (depending on client).



Draw sensor: starts recirc pump whenever a hot water draw is detected by a temperature increase at the tank outlet, but wait time is somewhat higher.



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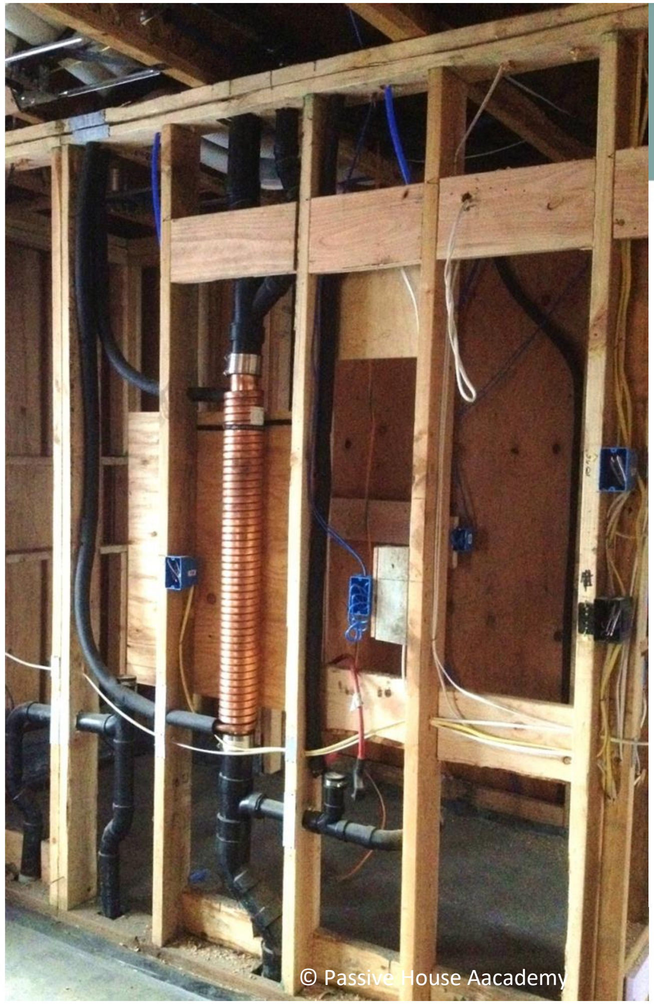
Domestic Hot Water

Heat Recovery from Drainwater

- Copper piping coiled around drain from upstairs showers and sinks
- Heat from drain water partially exchanged to mains water entering building
- Reduced primary energy consumption
- Efficiencies range from 40% to 75% (see Passive House Institute for certified systems)



© Passive House Aacademy

CERTIFICATE

Certified Passive House Component

Component-ID 0765sr03 valid until 31st December 2018

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category:	**Shower Water Heat Recovery**
Manufacturer:	**Wagner Solar GmbH, Cölbe, Deutschland**
Product name:	**Duschrohr ECOshower 15**

This certificate was awarded based on the following criteria:

Tested under standard boundary conditions[1] the system reduces the useful energy demand for shower by

54 % ≥ 30 %

steady-state efficiency
66 %
effective dead time
5 s
design flow rate
8 l/min

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System insulation

Losses, insulation, optimisation

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Heating pipes

Insulation of Space Heat Distribution Pipes

As a basic principle: Use short runs, especially outside the thermal envelope (best to avoid any distribution outside the enclosure entirely)

Heating pipes:

- Insulation thickness outside the thermal envelope: 1.5 to 2 times the nominal diameter
- Reduce thermal bridges at fittings, taps and pipe clips (keep insulation **continuous**)

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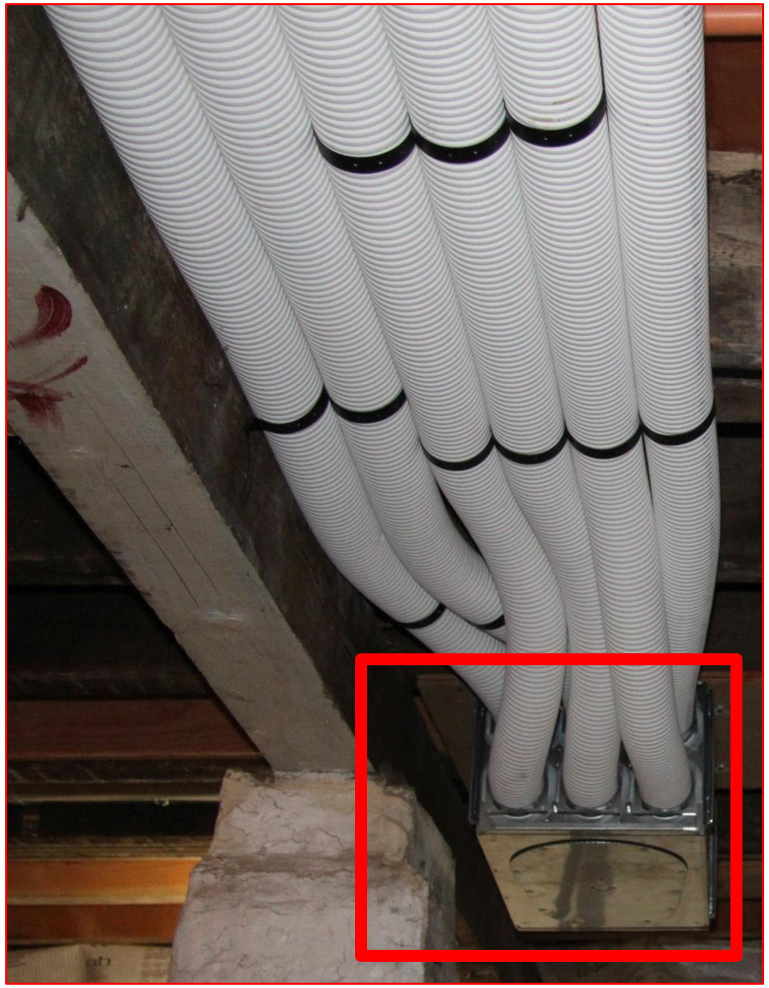
Ventilation ducts

Insulation of Space Heat Distribution Ducts

Ventilation ducts:

- Ducts between the ventilation unit and the thermal envelope must be very well-insulated - at least 100 mm, unless ducts are very short (< 0.6-0.9 m) in which case 50 mm may be sufficient.
- For supply air ducts inside the thermal envelope with heated or cooled supply air, insulation of 25 mm is sufficient.
- Insulation cover will also be required on manifold boxes.
- Insulation is not required for supply and extract air ducts inside the thermal envelope if the air is neither heated nor cooled (it will be very close to room temperature).



The small diameter ducts are becoming very popular in the home ventilation industry because they are easy to fit.

They MUST be insulated if they are transporting conditioned air. This will add to their diameter and make them more difficult / award to install.

The metal manifold box must also be insulated!

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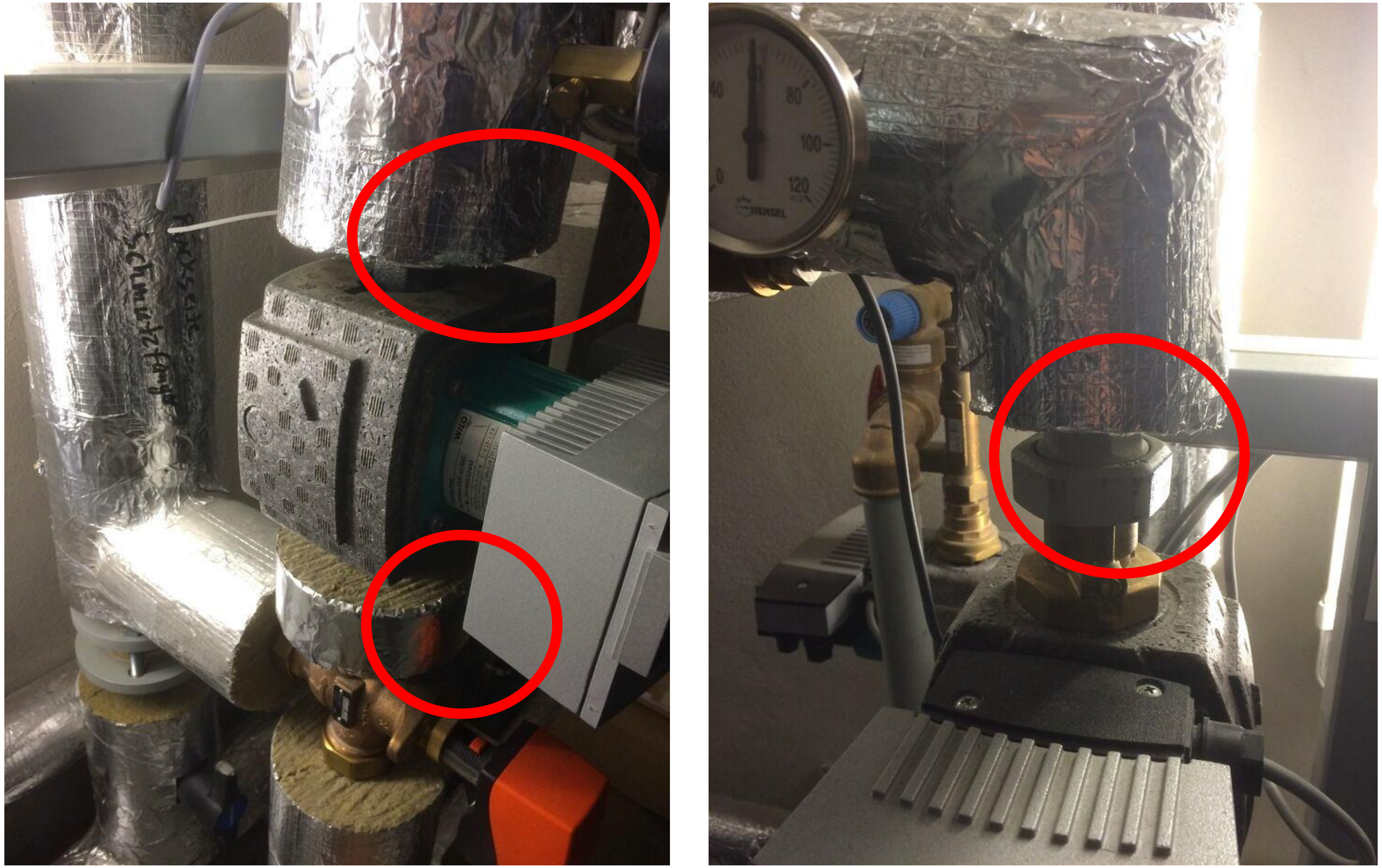
DHW pipes

Insulated Valve Jackets

Gaps in hot water pipe insulation result in unrecoverable energy losses and contribute towards overheating in summer

Do yourself a 50-year favor - finish the insulation completely and be done with it for good!



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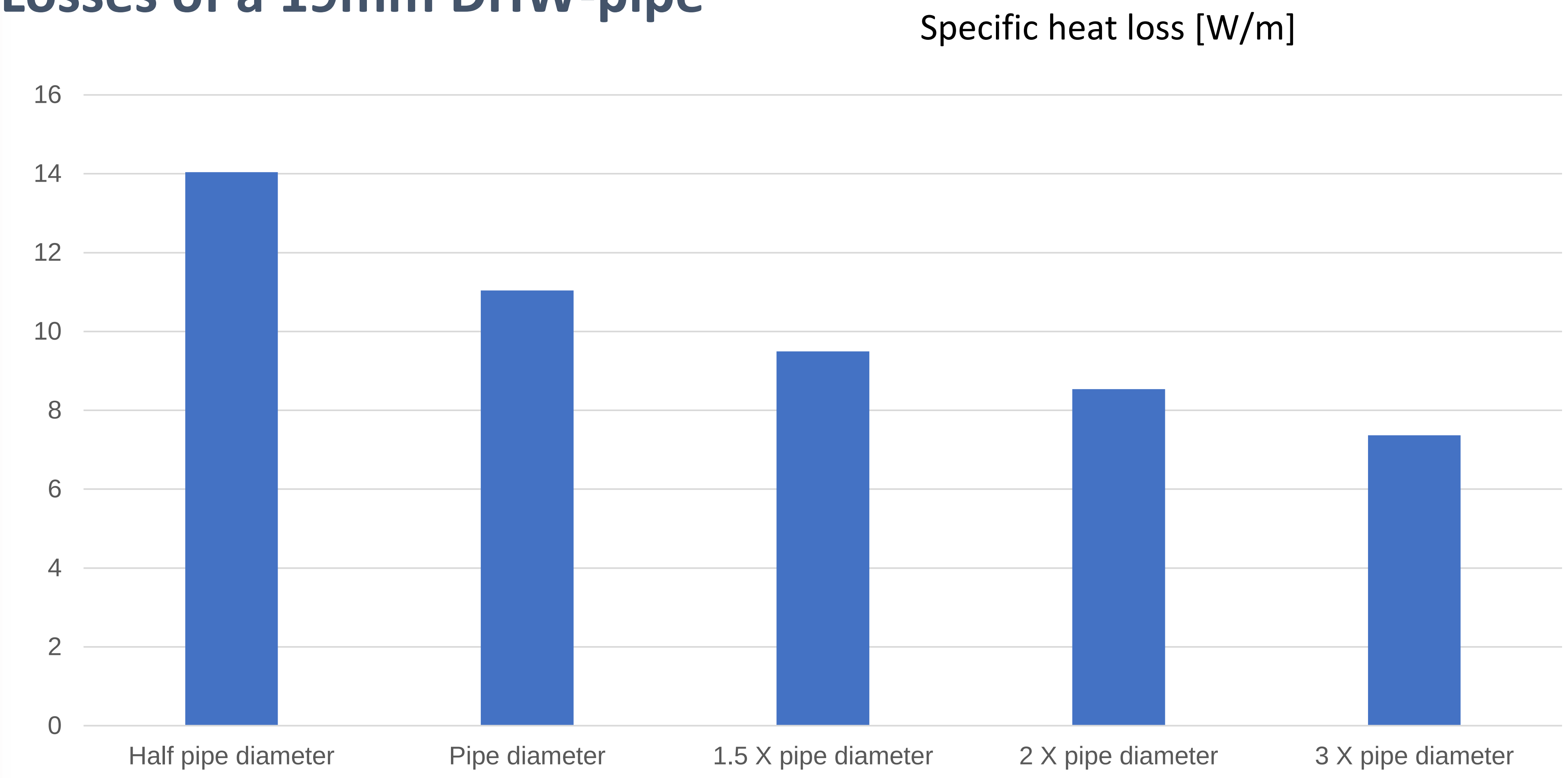
DHW pipes

Losses of a 19mm DHW-pipe



Assumptions: flow temperature of 60˚C, insulation conductivity of 0.04 W/mK with reflective coating

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Risks in implementing a stepwise approach considering building envelope

- Building systems pipes, cables and others passing through thermal insulation or airtight layers
- Too early change of heating system can cause oversizing
- MHVR before airtight layer may need a new setting after installing airtightness
- MHRV one or several steps after an airtight layer can cause problems with indoor air pollution and highly humidified air

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Examples

Create a Service Zone Inside of Vapour Control Layer could also be very useful for future systems

Source: Empowerhouse,
ns/Stevens Solar Decathlon 2011

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Examples

Carefully choosing the right moment to change the heating source can secure highly efficient systems together with low temperature heat source using the same heating installation.

	Heating demand	
Before	90 W/m2	36 kW
Step 1	70 W/m2	28 kW
Step 2 New heating system	46 W/m2	19 kW
Step 3	39 W/m2	16 kW

2.25 times less

iBRoad2EPC

Test Questions

1. Is it necessary to install a heating unit under the windows in a NZEB building (mark all correct answers)?

   a. Yes, it is mandatory to have a radiator or similar under the windows to compensate for the cold from the window regardless of the circumstances
   b. Yes, because in a NZEB there is a low surface temperature on the floor
   c. No, because a NZEB has ventilation combined with warm surrounding elements
   d. No, as long as the heating system is installed after the ventilation, windows and air tightness measures have been implemented

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Test Questions

2. Indicate the true statements:

   a. Heating demand in the renovated building according to NZEB standards is in some cases more than 5 times lower than heating demand in the same building before renovation, so if there are no other reasons, it is best to carry out the new heating installation towards the end of the renovation strategy
   b. Most energy recovery ventilation systems can recover about 70-80% of the energy in the exhaust airstream and deliver that energy to the incoming air for conditioning purposes
   c. Residential buildings with a Heating demand lower than 15 W/m2 can be heated only through the ventilation installation
   d. Residential buildings with a heating demand higher than 25 W/m2 can only be heated with a ventilation installation

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Test Questions

3. Indicate the true statements:

a. Some elements of air ducts and hot water pipes may not be thermally insulated, for example pipe fittings or collectors, as long as the main part of the pipes are insulated
b. Domestic hot water recirculation can cause a lot of losses in the installation if not controlled properly
c. Cold pipes in the building may not be thermally insulated
d. Energy consumption for DHW in the building after full renovation to NZEB will most likely be more than heating energy consumption

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Test Questions

4. At what air temperature is it possible for dust particles to start smoldering and emit an unpleasant smell:

a. 42
b. 35
c. 52
d. 100

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Thank you
for your time and collaboration

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