How important are control considerations when replacing boilers with heat pumps?

This is a summary of the latest of our ongoing series of webinars on decarbonising buildings. Its purpose was to de-mystify the process and provide guidelines about how to start, how to implement and follow up actions.

When embarking on a decarbonisation journey, the replacement of existing boilers with heat pumps seems an obvious thing to do. Currently, around 50,000 heat pumps are installed every year in the UK, and this is set to rise to 600,00 a year by 2028. Whilst the vast majority of these are successfully installed, it is not as simple as just replacing one technology with another. Indeed, the entire control strategy needs to be rethought.

Where to Start

Decide on your goals

You need to decide at the outset what the objectives of the project are and share them across the organisation. Why are you choosing to replace boilers with heat pumps? How will you measure success?

Aside from the cost of the actual project, have you considered the impact on running costs? Gas is still about a third of the price of electricity, so by electrifying your heating, your electricity demand and therefore costs will probably go up. Is management aware of this?

You need to understand the way that your building is used in order to plan effectively.

Know where you are currently

Now that you know where you want to get to you need to understand where you are now in terms of control. Research has shown that 80% of buildings across the EU and UK are energy inefficient and that by getting the control strategy right, savings of typically 30% can be achieved. Correcting this inefficiency before specifying new plant can lead to savings in both capital costs, e.g. by specifying smaller heat pumps, and also in ongoing energy costs by reducing demand

How then can you quantify this? The answer is by auditing your building and its control strategy using the international standard ISO 52120. Such an audit will assign an energy efficiency rating (like the one on your new refrigerator), from Class D, which is an energy-inefficient building, through Class C which is the benchmark, up to Class A, which is the highest level of efficiency. Class A buildings are demand-led, i.e. they do not run on timers, but rather use sensors that detect when rooms are unoccupied and so turn off building systems such as heating or lighting.

The Standard can also highlight areas where this can be improved, leading to higher efficiency. It can even estimate the savings in cost and carbon that could be achieved and how quickly the ROI will be achieved.

In addition, a good metering strategy with multiple sub-meters, the information from which is fed back into your BEMS system and gives further insights into trends and a greater understanding of your energy usage.

What's not being changed?

It's not as simple as replacing a 50kW boiler with a 50kW heat pump.

Before you begin to think about specifying a heat pump, you need to look at the nature and condition of what's not changing. How is the heat distributed across the building? What are the radiators like? What are the fan convectors like: do they need cleaning or servicing? Are there any pre-existing faulty components?

Another consideration, if you have air handling units, is whether the mechanical coil is sized appropriately for the lower operating temperatures and different flow rates that heat pumps work to.

Whilst the internal part of the heat pump will occupy approximately the same space as a boiler, it would normally be installed with buffer capacity to allow heat to be stored which would require additional space in the building. In addition, there is a requirement for an additional unit, outside the building. Is there space for this, and can planning permission be obtained?

Is the BEMS control panel appropriate for the new control strategy or will it need to be replaced?

The Heat Pump

When most people refer to heat pumps they mean air-to-water systems, whereby heat is extracted from the outside air and used to heat water-based systems for heating and hot water systems in the building.

Air-to-air pumps are typically used in air conditioning systems and as space heaters, due to their simpler design and lower install costs.

Both are used extensively but present different challenges in terms of design and control.

Coefficient Of Performance (COP)

This is used to measure the efficiency of a heat pump. This is the ratio of the energy consumed by the machine, versus its output in terms of heat. For example, in a 5kW heat pump, 4kW is captured from the outside air and 1kW is used to drive the machine, i.e. the ratio of 4:1 gives a COP of 4.

However, the efficiency of the pump will vary depending on several factors, principally the external air temperature and the flow temperature required to be delivered to the heating system.

If the outdoor air temperature (OAT) drops, the efficiency of the pump also drops: there is less energy outside to extract so the unit has to work a lot harder.

For consistency, to allow comparisons between different pups, they are recorded at fixed nominal conditions, specifically an OAT of 7ºC, and 35ºC flow temperature. Because of this, a variant called the Seasonal Coefficient of Performance (SCOP) uses seasonal data to look at the efficiency across the year (EN 14825).

Similarly, the higher the flow temperature, the lower the efficiency of the pump.

This is why getting the correct design, and the right control strategy is crucial.

The fact that a heat pump works at a lower flow temperature than a boiler means other considerations come into play.

Is there sufficient capacity in the electricity supply to support the heat pump?

Are the heat emitters adequately sized to work with the lower flow temperatures? If not there would be a requirement to, for example, up-size radiators or switch to alternatives such as underfloor heating, or fan-assisted convectors.

The existing pipework needs to be considered – whether the minimum flow rates are achieved. Narrow piping may need to be replaced to facilitate the minimum flow rate.

Defrost Cycle

This is a new problem that boilers don't face and is unique to heat pumps. In extracting heat from the outside air, the external coil can freeze up, thereby dramatically reducing the efficiency of the pump. To prevent this the pump reverses the direction of the heat to melt the ice, but this heat is drawn from the building heating system, so sufficient volume has to be incorporated in the design to prevent this from impacting on the internal temperature.

On larger installations with multiple units, these can be cycled by the control strategy to prevent all units from going into defrost at the same time.

Night Set back

When moving away from 80ºC boilers which heat the space quickly to lower flow temperature heat pumps, expectations need to change. Running things through the night ensures that the building does not get as cold and achieves a better recovery rate. This is more energy and cost-efficient than running the pump hard.

Ventilation

Heat recovery on the ventilation system is essential to ensure that not too much heat is lost

Electric Immersion Heaters

As a general rule when designing a system, it is advisable to include immersion heaters, both as a backup and to speed up the defrost cycle without impacting the building.

Implementation

Good Control Practice

Good control practice still applies and the heat pump should be integrated with other building systems, even if the pump comes with its own controls. Having a "single pane of glass" allows the building manager to better understand what's going on

Setpoints at an optimum level. Create a deadzone whereby there is a gap between heating and cooling setpoints.

A heat pump on its own will not decarbonise without an appropriate control strategy.

Control different places using zones to manage efficiency

Turn things off if not needed

Watch out for manual overrides

Running Costs

As mentioned earlier, electricity costs 3x the price of gas. Energy efficiency through good control is essential to mitigating this difference. That said, it is unavoidable

If appropriate, it may be worthwhile to install PV (solar) on-site, to mitigate this additional cost, possibly also wind depending on circumstances. These could be linked to the BEMS so that solar was used on sunny days rather than using energy from the grid.

Remote access allows more efficient running and reduced the cost of sending engineers to the site.

Maintaining the System

Seasonal commissioning

Aside from weather considerations, spaces are used differently at different times of the year, so seasonal commissioning needs to be considered ahead of time.

User Training

Running a heat pump is very different to a boiler so the appropriate staff need to be rainied in how to operate them efficiently

Maintenance

Clogged filters mean increased energy rates and increased failure rate.

Conclusions

Heat pumps are an important tool in decarbonising your building, but they need careful planning, an appropriate control strategy and regular maintenance.

Regardless of the technology good practice still applies – use a demand-based control strategy to minimise waste

Consider the whole building system holistically and use the space requirements and various sub-systems to complement each other

Our advice is to always talk to a specialist.

For a better world of energy

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