Earth Notes: TRVs and Heat Pumps: Heat Demand Down But Electricity Demand Up?

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Is there a fundamental clash between TRVs and UK heat pump retrofits such that regulation and user advice should change?

^ research home

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See: White Paper: OpenTRV North London Homes Trial (2015 to 2017)

See also:

- UK Wet Heating Retrofit PhD Research
- UK Homes Needing Wet Heating Retrofits: Status (2023)
- GitHub TRVmodel^ [hart-davis2023TRVmodel] and sample calculation output

To meet climate goals UK home heating must decarbonise. About 20 million gas-fired radiator systems are expected to be replaced with heat pumps. Many of those systems currently have TRVs (Thermostatic Radiator Valves) that help avoid overheating, improve comfort and save energy. These benefits can be larger for older and partially-occupied homes. Some heat-pump installers are concerned that TRVs and heat pumps work badly together, using more energy rather than less. This is usually not a problem for systems using weather compensation which sets radiator temperature based on outside temperature. But very 'stiff' room temperature control may waste a lot of energy.

To meet the UK's Net Zero targets, the 10% to 20% of UK greenhouse gas emissions from home heating will need to be cut [reguis2021challenges] [govUK2022boiler].

There are very few gas boilers that cannot be reasonably replaced with heat pumps, the UK's Climate Change Committee (CCC) and others make clear. Heat pumps can work well for all home ages and types [CCC2019technical] [rivers2020retrofit] [rivers2020decarbonising] [ESC2022EoH] [ESC2021suitable] [cockroft2017potential] [hart-davis2023retrofits]. Some individual homes will be hard to retrofit though.

About 80% of UK homes are heated with gas-fired radiators [henretty2020efficiency]. To be fully in line with building regulations and guidance (eg England's part L) [govUKconservation] [gambling2023misinterpreting] most of those radiators are fitted with thermostatic radiator valves (TRVs).

TRVs help stop rooms getting too hot and wasting energy. Some homes heat unevenly: maybe rooms catch a lot of sun some days. Some people sleep better in cooler bedrooms. And bedrooms do not usually need to be warm during the day even when the rest of the home does. Heating a room that is not being used, such as a spare room, can also be a waste.

Some heat-pumps installers are concerned when replacing a gas boiler. For example, maintaining sufficient flow for a heat pump to work efficiently, and having sufficient volume to support defrosting of an Air Source Heat Pump (ASHP).

But Heat Geek and others have brought up a potentially more fundamental issue.

> We wouldn't necessarily advise using TRVs or room stats to turn down unused rooms or spare rooms either. Turning unused rooms right down, or micro zoning, gives a particularly high risk of losing efficiency for heat pumps.
> [chapman2023zone] extracted 2023-06

Also:

> ... if you are in the habit of turning down the radiator in the spare room, you should turn it on again after having a heat pump installed. Either that or insulate the walls and floor/ceiling to minimise heat leakage from the rest of the house. This is an interesting example where what we learned about energy saving with gas boilers has to be modified for heat pumps. They are a different game entirely.
> [terry2021unused] extracted 2023-08

These TRV concerns were tested: would they be a real problem for most homes? Can we combine TRVs with heat pumps to save energy and money, and be in more control of our home?

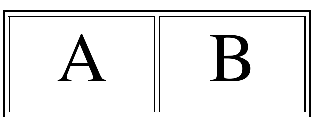
Analysis

A simple model was constructed to match the Heat Geek setup. It was extended to a more common UK house type. It was tested with a ten years of hourly weather data for seven UK locations.

The model and the data are published open source [hart-davis2023TRVmodel]. A copy of the main calculation output is also available.

Key points of the Heat Geek set-up:

1. Four equal-size square rooms (each 4m on a side) in a square grid.
2. Can be treated as a bungalow.
3. The outside is at -3°C, the UK average winter outside design temperature.
4. Normally all rooms are at 21°C, and the home then loses 2000W to the outside. So 500W is being supplied by the radiator in each room.
5. During setback two of the diagonally-opposite rooms are allowed to drop to 18°C, using TRVs.
6. During setback the house heat demand *drops* a little over 6% thanks to the TRVs.
7. During setback **the heat-pump flow temperature is raised to maintain the other two rooms at exactly 21°C**, as they leak heat through the internal walls/doors into the set-back rooms. This is critical.
8. But raising the flow temperature reduces the CoP (Coefficient of Performance) of the heat-pump by more than the heat demand drops.
9. So during setback, the electricity demand of the heat-pump goes *up* nearly 6%.
10. A heat saving becomes an electricity hike.



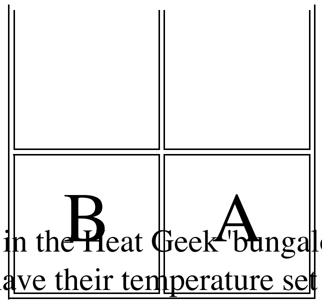


Figure 1: 'ABAB' layout of rooms in the Heat Geek 'bungalow' as seen from above. A rooms are always at 21°C. B rooms can have their temperature set back to 18°C. B rooms may be unoccupied, or bedrooms kept cooler for sleeping comfort.

The 'bad setback effect' still happens when extending the bungalow to a 2-storey detached with its different surface-area to floor-area ratio. Detached homes are a little under 18% of English homes and the third most common building type, compared to about 7.5% for bungalows [EHSprofile].

The 'bad setback effect' also shows up when using hourly external temperatures for a decade in seven UK towns and cities including London and Glasgow.

This bad setback effect reduces on warmer days, with TRVs not making things better or worse for the Heat Geek bungalow at about 10°C outside.

Switching to an 'AABB' room layout (or insulating the walls) mutes the bad setback effect but does not stop it. TRVs and zoning still seem to end up wasting energy, or barely saving any.

Temperature Regulation

The critical part of the Heat Geek scenario is that temperature regulation in the A rooms is 'stiff'. The rooms stay fixed at the 21°C setpoint.

Even in a conventional gas-fired system with a thermostat on the wall, temperature may vary by 1--2°C around the temperature chosen.

A more common scheme in heat pump installations is to use "weather compensation" to set the radiator flow temperature based on the outside temperature. The heat pump turns down and then off if rooms get too hot.

When flow temperature is driven entirely by weather compensation, A room temperatures would fall a little towards the B room 18°C setback.

This behaviour was observed in a Chinese apartment block [xu2023field]. Heated room temperatures fell at most ~1.5°C, 0.7°C on average.

In the Heat Geek bungalow the worst temperature sag is 1.6°C. For the detached house version, 2.0°C.

These are smaller with a less extreme zoning pattern such as AABB.

When this sag is allowed, heat pump electricity demand goes down in step with heat demand.

In other words, the bad setback effect goes away and the TRVs reduce heat *and* electricity demand.

A recent study indicates temperature tolerances of at least 2°C [berry2023flexibility]. So this may be entirely acceptable to householders.

Conclusion

For a typical weather-compensated heat-pump home the bad setback effect should not appear. Installers should therefore not reject TRVs out of hand, though there are other issues to be aware of. Zoning such as with TRVs is still useful, for extra savings, comfort and control.

Installers and householders should know that setting up 'stiff' control of room temperature may cost a lot more than they bargained for!

Thanks

Many thanks to Adam Chapman and Nicola Terry for providing clear worked examples of this potential bad setback effect.

Also thanks to the many people who helped review this analysis!

Significant Versions

Working Paper

Date	Text Version	Code Version
2023-09-21	V0.9.1 (first draft for comments) `.docx`	V0.9.1 ZIP
2023-10-02	V0.9.2 (second draft for comments) `.docx`	V0.9.2 ZIP
2023-10-09	V0.9.3 (third draft for comments) `.docx` `PDF`	V0.9.3 ZIP

References

- [berry2023flexibility] *Automating heat pump flexibility: results from a pilot^*
- [CCC2019technical] *Net Zero Technical report^*
- [chapman2023zone] *Why NOT to ZONE Heat Pumps or Boilers!^*
- [cockroft2017potential] *Potential energy savings achievable by zoned control of individual rooms in UK housing compared to standard central heating controls^*
- [ESC2021suitable] *Electrification of Heat: All housing types are suitable for heat pumps^*
- [ESC2022EoH] *Electrification of Heat: Home Surveys and Install Report^*
- [gambling2023misinterpreting] *Are Heating Manufacturers Misinterpreting Building Regs?^*
- [govUK2022boiler] *Open consultation: Improving boiler standards and efficiency^*
- [govUKconservation] *Conservation of fuel and power: Approved Document L^*
- [hart-davis2023retrofits] *UK Homes Wet Heating Retrofits Needed for Net Zero^*
- [hart-davis2023TRVmodel] *TRVmodel: TRV energy modelling in home heating^*
- [henretty2020efficiency] *Energy efficiency of housing in England and Wales^*
- [reguis2021challenges] *Challenges for the Transition to Low-Temperature Heat in the UK: A Review^*
- [rivers2020decarbonising] *Decarbonising buildings with heat pumps^*
- [rivers2020retrofit] *Heat pump retrofit in London^*
- [terry2021unused] *Turning down the radiators in unused rooms^*
- [xu2023field] *Field tests to examine energy saving effects of occupants' thermostatic radiator valves (TRVs) regulating behavior in district heating systems^*

(Count: 17)

~1921 words.

1. Thermal Imaging Survey: DIY vs Professional
2. Open-Source Thermostatic Radiator Valve (OpenTRV)
3. Vent-Axia Lo-Carbon Tempra single-room MHRV: Review

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