Historic churches and the challenges associated with reaching net-zero

Simulating comfort from local heating systems

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For many churches 2030 is the year to achieve net-zero carbon. How can this be achieved with old inefficient heating systems that often struggle to provide enough comfort for occupants? Heating can be provided by using one or a combination of methods (Figure 1), the choice largely depending upon how many times the building is used in a typical week.

- For conservation purposes stable temperature and relative humidity are preferred over rapid fluctuations in temperature
- Achieving stable temperature is difficult in high thermal mass churches, due to sporadic usage patterns and high cost of energy
- Central heating systems are not demand responsive – being either on or off with no zonal control, no matter how many occupants are present
- Artefacts and artworks are generally safe when making changes to the heating system as they have adjusted to the altered conditions over many decades
- This research focuses on how changes to the heating system and strategy could increase comfort conditions for occupants. St Mary de Haura, Shoreham by Sea was used as a case study for the software modelling and physical collection of temperature and relative humidity data in 2019/2020
- Occupant comfort (predicted mean vote: PMV) was calculated to be at the coldest measurement on the PMV scale during 4th January 2020 (Figure 2: St Mary actual 10am & PMV 5pm)
- Using the model data in conjunction with calculations of local comfort systems and a background heating setting of 14°C, comfort for seated occupants with light clothing was increased closer to neutral comfort levels (Figure 2: PMV 10am & 5pm)
- Energy, emissions and cost savings were calculated – see Table 1 & Figure 3

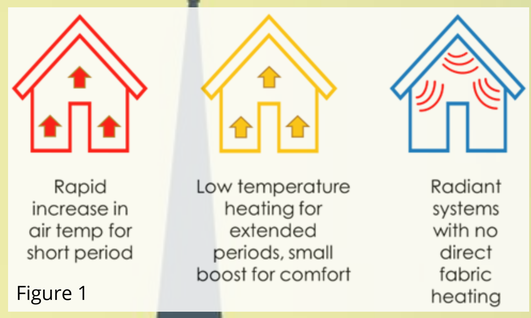


Figure 1

St Mary de Haura, Shoreham by Sea, West Sussex, 12th century church

Table 1

System for main zone	Total energy saving over boiler @ 20°C – kWh	Low cost (£): gas @ 3p/kWh + elec @ 17p/kWh	Medium cost (£): gas @ 10p/kWh + elec @ 34p/kWh	High cost (£): gas @ 28p/kWh + elec @ 84p/kWh	Emissions 2022 UK kg CO2e	Future 2040 emissions UK kg CO2e	Comfort PMV
Gas boiler - radiators @ 20°C	-	4,009	13,765	37,755	11,774	11,774	-
Gas boiler - radiators @ 14°C + Heated cushions	6,793	2,652	8,197	22,171	5,602	5,227	-0.77 and -0.27
Air source heat pump – radiators @ 14°C + Heated cushions	20,066	5,483	10,965	27,387	3872	261	-0.77 and -0.27

Figure 2: comfort predictions @ 14°C background heat 4th January

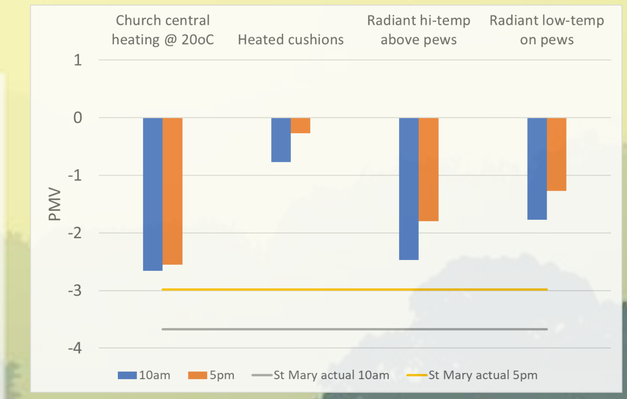
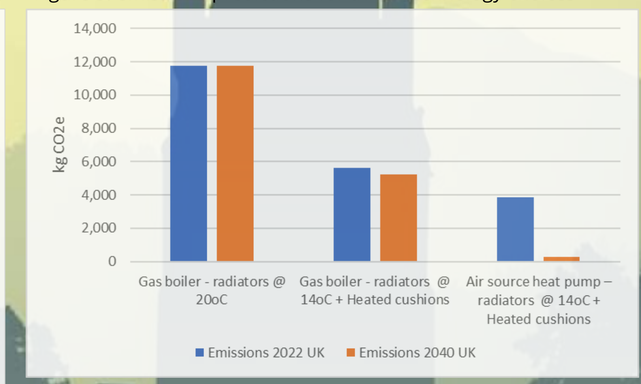


Figure 3: emissions predictions for three technology choices



Conclusions from simulations:

- **More stable background environment achieved if heating set for sustained 14°C**
- **Improved local comfort using low powered electrical options - heated cushions provided the best neutral comfort level. Less successful were radiant panels on pews and high temperature radiant systems, although they still improved local comfort with light clothing options**
- **A 52% reduction in carbon emissions (CO_2e) was calculated when using a gas boiler at 14°C with heated cushions**
- **Increasing to a 67% reduction if an air source heat pump replaced the gas boiler for background heating, with the addition of heated cushions**
- **Future 2040 low carbon intensity electricity would see a reduction of 98% in emissions when using an air source heat pump over a gas boiler @ 20°C setpoint**
- **Background heating @ 14°C could be turned off earlier in spring and turned on later in autumn, when only a small difference to outside temperature exists. Local heating devices would provide the required comfort level at lower cost and emissions than operation of the heating system**

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