

# Clean Heat Streets: Benchmark simulations for SMS

v1.0  
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8-9-2023

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# 1. Modelling assumptions

Simulations were run across a whole year at a half-hourly resolution, and profiles indicate the average power (as well as other variables) in a half-hourly period.

24 scenarios were modelled, corresponding to 6 archetypes x 2 occupancy types x 2 heating systems:

- Six different house archetypes were selected:
  - 2/3/4 bed terraced houses, and 2/3/4 bed semi-detached houses were modelled.
  - House types were used to select representative heating rates, thermal masses and other house thermal properties. These were determined by randomly sampling in line with our experience of typical UK housing stock.
  - The homes selected had average insulation.
  - Hot water tanks were sized such that the larger the property (more bedrooms), the bigger the tank.
- Two different types of occupant were modelled:
  - **Family.** All day heating schedule (07:00-22:00 weekday, 08:30-23:00 weekend) . High hot water consumption.
  - **Working couple.** Morning and evening heating schedule (07:00-09:00, 18:30-23:00). Medium hot water consumption.
  - Heating set points were randomly generated for each home but kept the same between occupant types to ease comparability.
- Two different heating systems were modelled:
  - **Gas boiler.** Assume thermostatic control which incorporates “optimum start” for equivalence with heat pump (in terms of room temperature comfort achieved). The house was assumed to have small radiators in these scenarios.
  - **Heat pump.** Heat pumps were sized appropriately, such that they are able to heat the house (to the desired room temperatures, at least). Radiators were assumed to be upgraded, such that they’re appropriate for use with a heat pump. The control strategy used our best guess at standard manufacturer controls, with weather compensated flow temperatures enabled. The simulations assume perfect modulation to maintain room temperature.

## Domestic hot water

- Simulation runs include both space heating and domestic hot water production.
- The limited capacity of the heat pump (for simultaneous heating and hot water production) is modelled.
- Hot water is included for completeness, only to give a broad indication on consumption levels. It should be noted that detailed models for hot water have significant limitations and the results should be treated very carefully. Specifically:
  - Hot water consumption is modelled using (scaled) draw profiles from real homes, however we assume the controller has perfect knowledge of this.
  - Both heat pump and boiler hot water control results in cylinders being topped up to 45°C constantly.
  - Heat pump CoP seems to be coming out a little high for hot water.

## **Weather**

- A home location of Oxford was used to determine the weather data for the simulation. Typical Meteorological Year (TMY) weather data was used in all simulations. The TMY data is selected by analysing historical data and finding real months of data which best match the long term averages of daily min/max temperature and daily irradiation.

## **Prices**

- Gas and electricity prices in the outputs are believed to be representative of current prices in Oxford, as of 7/9/23.

## 2. Data description

A **Run\_Description\_Summary.csv** is included, which shows the configuration used for each run and some totals across the simulation period. The columns are as follows:

- **Run number**
- **House type**: the type of house modelled.
- **Heating system**: whether the house uses a boiler or a heat pump.
- **AM\_Setpoint, PM\_Setpoint**: the temperatures to be targeted during heating periods in the morning and evening.
- **Schedule**: the period during which the heating system targets the setpoint.
- **Number of occupants**: number of occupants used to generate hot water consumption profile.
- **total\_heating\_price\_pounds**: Total heating cost (either through the heat pump or boiler) for space heating and hot water.
- **total\_heating\_fossil\_fuel\_in\_kwh**: total fossil fuel usage for space heating (for boiler runs).
- **total\_heating\_electricity\_in\_kwh**: total electricity usage for space heating (for heat pump runs).
- **total\_heating\_out\_kwh**: total energy output for space heating and hot water.
- **total\_sh\_fossil\_fuel\_boiler\_input\_energy\_kwh**: total fossil fuel usage for space heating.
- **total\_sh\_fossil\_fuel\_boiler\_output\_energy\_kwh**: total energy output for space heating from the boiler.
- **total\_hw\_fossil\_fuel\_boiler\_input\_energy\_kwh**: total fossil fuel usage for hot water.
- **total\_hw\_fossil\_fuel\_boiler\_output\_energy\_kwh**: total energy output for hot water from the boiler.
- **total\_sh\_heat\_pump\_input\_energy\_kwh**: total electricity usage for space heating.
- **total\_sh\_heat\_pump\_output\_energy\_kwh**: total energy output for space heating from the heat pump.
- **total\_hw\_heat\_pump\_input\_energy\_kwh**: total electricity usage for hot water.
- **total\_hw\_heat\_pump\_output\_energy\_kwh**: total energy output for hot water from the heat pump.
- **total\_carbon\_kgCO2**: total carbon emissions from space heating and hot water usage.
- **PercMissedSP** : percentage of heating setpoints missed by >0.25°C.
- **PercMissedTankSP** : percentage of hot water tank setpoints missed by >0.25°C.

A **HeatProfile\_X.csv** is included, which contains half-hourly data across the simulation period. The columns are as follows:

- **start\_of\_period\_UTC**: start of the half hourly period which the row of data is linked to.
- **set\_point\_C**: the requested comfort level by the user, taken from the weekly schedule configured in the system for that particular home.
- **room\_temp\_C**: the room temperature predicted during the half hour period.
- **SH\_water\_temp\_C**: assumed water temperature (SH only) during the half hour period.
- **tank\_set\_point\_C**: the target temperature for the hot water tank (assumed to be 45°C when the homeowner is expected to be in).
- **tank\_temp\_C**: the hot water tank temperature predicted during the half hour period.
- **external\_temperature\_C, irradiation\_kW\_m2**: weather conditions taken from the nearest Met Office weather station for a typical meteorological year.
- **fossil\_fuel\_boiler\_sh\_input\_energy\_kWh**: fossil fuels consumed by the boiler (where present) for space heating in this half-hour period.
- **fossil\_fuel\_boiler\_sh\_output\_energy\_kWh**: heat produced by the boiler (where present) for space heating in this half-hour period.
- **fossil\_fuel\_boiler\_hw\_input\_energy\_kWh**: fossil fuels consumed by the boiler (where present) for hot water in this half-hour period.
- **fossil\_fuel\_boiler\_hw\_output\_energy\_kWh**: heat produced by the boiler (where present) for hot water in this half-hour period.
- **heat\_pump\_sh\_input\_energy\_kWh**: electricity consumed by the heat pump (where present) for space heating in this half-hour period.
- **heat\_pump\_sh\_output\_energy\_kWh**: heat produced by the heat pump (where present) for space heating in this half-hour period. Indicates heat pump efficiency (for space heating) in comparison with the input electricity figure.
- **heat\_pump\_hw\_input\_energy\_kWh**: electricity consumed by the heat pump (where present) for hot water in this half-hour period.
- **heat\_pump\_hw\_output\_energy\_kWh**: heat produced by the heat pump (where present) for hot water in this half-hour period. Indicates heat pump efficiency (for hot water) in comparison with the input electricity figure.
- **electricity\_price\_p\_per\_kWh**: price per unit of electricity for this half hour period.
- **fossil\_fuel\_price\_p\_per\_kWh**: price per unit of fossil fuel for this half hour period.
- **heating\_electricity\_in\_total\_kWh**: total electricity consumed by the heat pump (where present) in this half-hour period.
- **heating\_electricity\_out\_total\_kWh**: total heat produced by the heat pump (where present) in this half-hour period. Indicates overall heat pump efficiency in comparison with the input electricity figure.
- **heating\_fossil\_fuel\_in\_total\_kWh**: total fossil fuels consumed by the boiler (where present) in this half-hour period.
- **heating\_fossil\_fuel\_out\_total\_kWh**: total heat produced by the boiler (where present) in this half-hour period.
- **heating\_electricity\_cost\_p**: price of electricity consumed for the half hour period.
- **heating\_fossil\_fuel\_cost\_p**: price of fossil fuels consumed for the half hour period