In its efforts to reduce CO₂ emissions, the UK government has encouraged the adoption of electrical heat pumps for space and hot-water heating in all building types. Unfortunately, the country’s experience of domestic electrical heat pumps has been mixed, with field trials demonstrating poorer performance than anticipated. Despite subsidies, this dissatisfaction is compounded by the relatively low cost of natural gas and the high cost of a heat-pump installation.

The European Union (EU), via Ecodesign directive 2009/125/EC, has sought to enhance the efficiency of energy-consuming products sold within it, with minimum standards and energy labels as key features. This directive has had considerable success in improving the efficiency of a wide range of products.

The EU Ecodesign regulations No 811/2013 and 812/2013 – which came into force in November 2015 – apply to electrical heat pumps and give a seasonal coefficient of performance (SCOP) estimate for space heating. Separate hot-water efficiency estimate is also given when a hot-water cylinder is sold as part of the heat pump package.

There is a problem with the Ecodesign regulations, though, because they estimate space and/or hot-water efficiency as a product, not as part of a dwelling heating system. They also assess space and hot-water heating services independently, when they affect each other.

While the test data requirements are comprehensive (EN14825 test and calculation standard used to estimate space-heating efficiency, and EN16147 test standard used to estimate hot-water heating efficiency), the regulations miss essential criteria for accurately determining heat pump performance as part of a domestic heating system:

- **Plant size ratio (PSR)** – design heat pump output divided by design heat load; Ecodesign assumes 1
- **Backup heating** (effectively ignored)
- **Hot-water load estimate for actual dwelling** – hot water is ignored within the SCOP calculation
- **Operating hours** – the SCOP calculation ignores the effect of intermittent heating, which is prevalent in the UK
- **Design flow temperature** – only two options: 35°C or 55°C
- **Hot-water cylinder characteristics** – the SCOP calculation ignores hot-water operation
- **Minimum modulation rate** – some inverter heat pumps can modulate minimum heat output to a lower level than others, avoiding on/off cycling
- **Weather compensation** – the SCOP calculation assumes weather-compensation control is always present and active
- **UK weather** – the SCOP calculation uses European average weather data, which is less accurate for UK purposes

**Figure 1: Hot-water energy consumption vs space-heating load**

\[ y = 1760.3x^{0.1818} \]

\[ R^2 = 0.6952 \]
Example calculation results

The ability to interrogate hourly calculation-method results, using the developed calculation engine, is a useful facility that could be employed for many purposes. Figures 3.4 and 5 display example results for the same heat pump:

- with a PSR of 0.8 – where the operating hours vary from 24 hours a day for the coldest day of the year, to 16 and 11 hours on the coldest days that can be supported by these reduced operating hours. The design-flow temperature for the heat emitter system was 55°C. The heat pump in this example must operate for longer to satisfy the standardised SAP heating profile requirement. These figures show that:
  - Where a hot-water demand exists, some or all of the space-heating demand on these days must be satisfied by direct electric heating.
  - Operating hot-water heating at times of peak-space-heating demand is not optimal. This may not be in some or many installations in practice, but it is still commonplace.
  - The heat pump is able to deliver a larger amount of energy during hours when the ambient (source) temperature is higher (Figure 5).

Calculation method validation

To determine if the calculation method gives a reasonably accurate estimate of a heat pump systems annual efficiency, it was validated. This included reviewing data, supplied by University College London (UCL), which analysed data from the Renewable Heat Premium Payment (RHPP) metering programme for the government, comprising 700 heat pump installations.

While measurement uncertainty exists – and no design heat-load calculation method – incorporating EN14425 test data – was needed. A significant element of the revised method, developed by BRE, was an annual, combined, space- and hot-water heating duty cycle, incorporating hourly heat load and temperature assumptions for a typical UK domestic system. It includes hot-water draw-off times based on a scaled version of EN1647 Profile M, with energy requirements derived from field trials. The combined duty cycle is used to estimate annual efficiency using a UK domestic system. The method is based on EN316-4.2-2017 and uses EN14425 test data.

Method

The SAP heat pump calculation implements EN316-4.41 hourly time-step approach because of the issues discussed above, but with considerable customisation and specification of UK dwelling variables. The calculation method is entitled ‘Calculation Method: CALCM:01 – SAP Revised Heat Pump Performance Method’.

The method performs coefficient of performance (COP) calculations for each hour, or fraction of it, depending on the heating service being delivered (space or hot water), the required flow (sink) temperature, and the source (air or ground) temperature. The annual efficiency estimate is calculated by dividing total energy outputs by total energy inputs. Hot water is a significant proportion of domestic energy use; the average consumption of UK homes – based on 24 occupants and 80 litres of hot water at 58°C – is about 44 kWh per day. This figure, based on Energy Saving Trust data, varies between homes.

The basis of the heat pump calculation method is that average hot-water demands must be met before space-heating demands, with any deficits satisfied by backup direct electric heating. A standardised schedule for hot-water consumption, based on EN1647 Profile M, is used with energy consumption adjusted according to the ambient temperature. The standardised schedule and energy consumption adjusted according to the ambient temperature. The standardised schedule and energy consumption adjusted according to the ambient temperature.

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