HOME TRUTHS

Accurately predicting domestic electrical heat pump performance is vital if the UK is to encourage their adoption. But the EU's Ecodesign regulations do not account for vital criteria. A better method is needed, says BRE Group's **Will Griffiths**

In its efforts to reduce CO_2 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 »

MISSING CRITERIA

The regulations miss the following criteria essential 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**

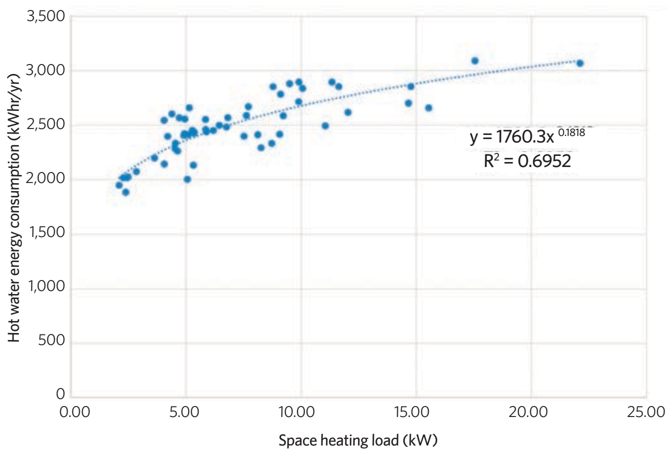

Figure 1: Hot-water energy consumption v space-heating load

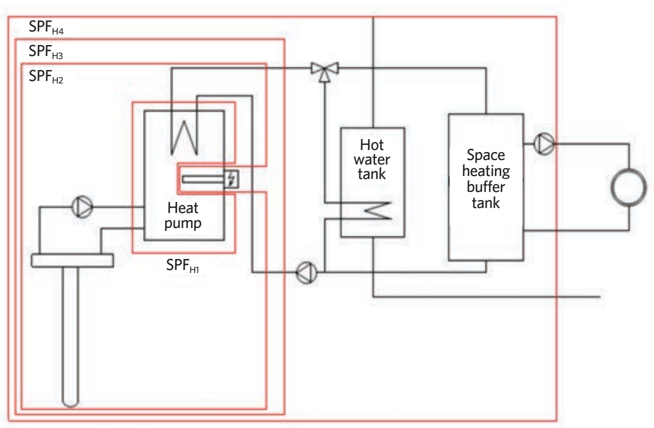

Figure 2: SEPEMO system boundaries to determine heat pump annual performance[6]

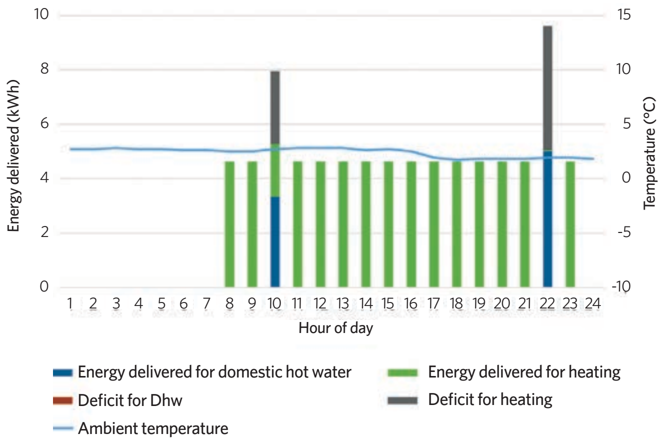

Figure 4: Example heat pump – energy delivered on the coldest day of the year on which 16-hour heating is supported, with PSR = 0.8

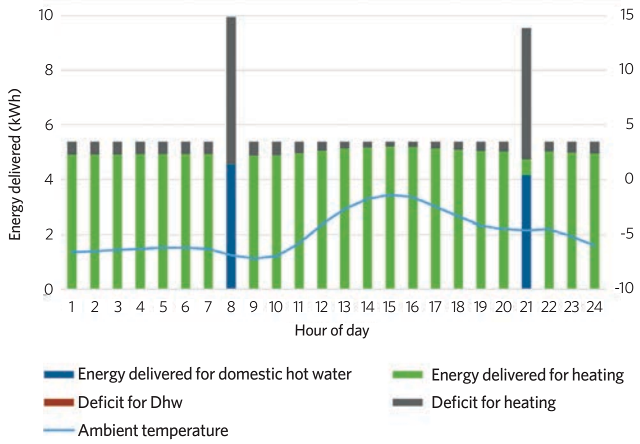

Figure 3: Example heat pump – energy delivered on the coldest day of the year (24-hour heating), with PSR = 0.8

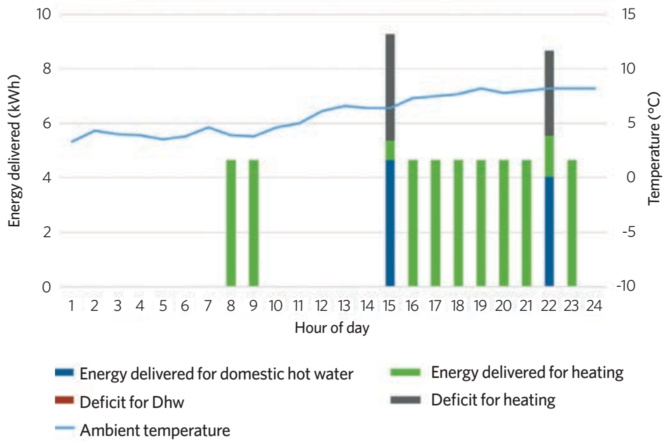

Figure 5: Example heat pump – energy delivered on the coldest day of the year on which 11-hour heating is supported, with PSR = 0.8

» pump performance in UK homes. See panel, 'Missing criteria'.

If reasonable confidence in performance estimates – namely the annual efficiency – cannot be guaranteed, then the long-term uptake of heat pumps also cannot be assured. This problem is particularly acute, given the commercial competitiveness of condensing boilers and the low price of natural gas.

Since 2010, the calculation methodology for energy rating of UK dwellings – SAP – has incorporated heat pump performance data. This was achieved via the Product Characteristics Database (PCDB) using EN14511:2007 test data at defined conditions and a modified version of the calculation method EN15316-4-2:2008 – a bin method.

Ecodesign regulations require all heat pumps to be tested in accordance with EN14825, so SAP's previous test-data requirements have become obsolete. The SCOP is also unsuitable because SAP requires annual efficiency for the heat-generator system, not the product alone. Nevertheless, the heat pump product test conditions and data arising from the EN14825 standard are highly useful, so a revised SAP heat pump calculation method – incorporating EN14825 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 EN16147 Profile M, with energy requirements derived from field trials.[1,2] The combined duty cycle is used to estimate annual efficiency using UK average (Leeds) weather conditions. The method is based on EN15316-4-2:2017 and uses EN14825 test data.

Method

The SAP[3] heat pump calculation implements EN15316-4-2's[4] 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'.[5]

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 2.4 occupants and 80 litres of hot water at 55°C – is about 4kWh per day. But this figure, based on Energy Saving Trust data, varies between homes.

The basis of the heat pump calculation method is that average hot-water energy 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 EN16147 Profile M, is used, with energy consumption adjusted according to the assumed dwelling heat loss (see Figure 1). Values were determined using English Housing Survey data.

For the purposes of SAP – and, arguably, any reliable system-comparison metric – the system boundaries used within this calculation method are identical to the SEPEMO SPF H4 definition (Figure 2). This incorporates all electrical-energy consumption from the space and hot-water system, which includes circulation pumps and backup heating.

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 occur 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 system's 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 information for RHPP installation sites is available – the calculation method gives reasonable agreement with measured results, and with earlier studies. It is also clear that Ecodesign SCOP values appear to over-predict performance.

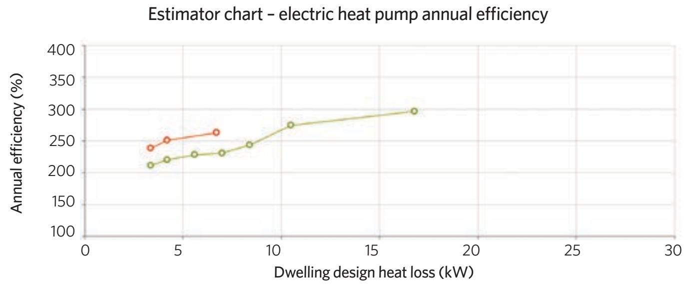

Figure 6: Different heat pumps

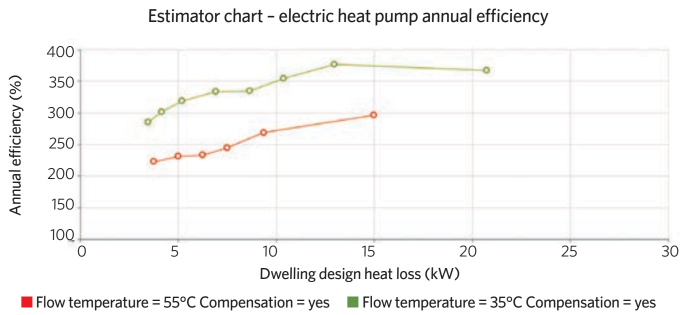

Figure 7: Same heat pump, different design-flow temperature

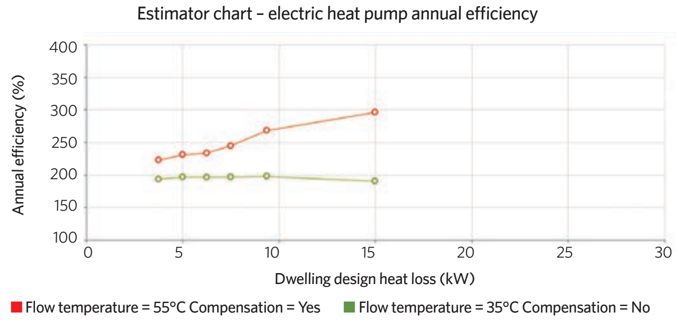

Figure 8: Same heat pump, weather compensation on or off

> "The regulations miss essential criteria for accurately determining heat pump performance in UK homes"

Heat pump performance estimator website

For SAP purposes, heat pump annual efficiency values are calculated by the revised method and held within the PCDB. This has data records for each heat pump submitted by manufacturers and processed by BRE.

To encourage use of the wide range of annual efficiency estimates held in the PCDB, BRE developed **www.bre.co.uk/heatpumpefficiency**.

Figures 6-8 show the website's ability to display the effect of product selection, design-flow temperature and weather compensation on annual efficiency. The x-axis is presented in terms of the dwelling heat loss (kW) and relates to the PSR. CJ

WILL GRIFFITHS is head of NCM technology recognition at the BRE Group

References:

1 Energy Monitoring Company on behalf of Energy Saving Trust. Measurement of Domestic Hot Water Consumption in Dwellings; 2008.
2 Shorrock L, *Analysis of the EST's domestic hot-water trials and their implications for amendments to BREDEM and SAP*. BRE; 2008.
3 BRE on behalf of DECC. The government's Standard Assessment Procedure for energy rating of dwellings, 2012 edition. 2013 (revised 2014).
4 Energy performance of buildings – Method for calculation of system energy requirements and system efficiencies – Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2.
5 SAP revised heat pump performance method, Issue 1.2, **bit.ly/2oJSBuw**
6 Nordman R, *Seasonal Performance Factor and monitoring for heat-pump systems in the building sector*; 2012.

Acknowledgements

The Department for Business, Energy and Industrial Strategy funded the development of the heat pump calculation method as part of BRE's contract to maintain and develop the National Calculation Methodology (NCM) for energy rating of dwellings (SAP). UCL supplied unpublished data to BRE for the purpose of validating calculation method results.