Improving the Efficiency of Domestic Electric Water Heaters: Past Experiences and Future Prospects

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Synopsis

This paper investigates the technical and economic potential of raising the energy efficiency of domestic electric water heaters in the European Union.

Abstract

This paper reports intermediate results from an on-going SAVE sponsored study to investigate the technical and economic potential of measures to raise the energy efficiency of domestic electric water heaters in the EU. After refrigeration, electric water heating constitutes the second most important residential electric end-use, accounting for ~18% of all EU domestic electricity consumption (~70TWh/year).

Introduction

Some 31 % of households in the European Union use electricity for water heating, but the type of water heating system can vary from country to country. The two principal systems are: a descentralized approach by which a number of small 'instantaneous' water heaters are positioned at each point of demand (e.g. the shower/bath, and each sink); and a centralised approach wherein a single large 'storage' water heater is used for the whole household. In total, there are an estimated 45 million domestic electric water heaters in the European Union, of which approximately 15 million are of the small 'instantaneous' type (<15 litres), and 30 million are the larger storage type (see Figure 1). The descentralized instantaneous system is more typical in Germany, while the centralised storage system is favoured in the rest of Europe. The choice among electric water heating systems is strongly influenced by the local tariff structure such that in several countries centralised storage water heaters have been promoted by the utility over many years in order to maximise demand for low-cost off-peak electricity and to flatten the load curve.

Analysis

The energy balance analysis of a water heater differs from many appliances because it is most appropriate to consider the water heater as a component part within an entire hot water delivery system rather than as stand-alone appliance. Total hot water energy consumption may be divided between the use (which can be reduced by efficient end-use appliances), the pipe losses and tank losses. However, this paper is concerned solely with the means of improving the efficiency of storage type water heaters (>15litres) as a precursor to developing European energy policy for tradable appliances.

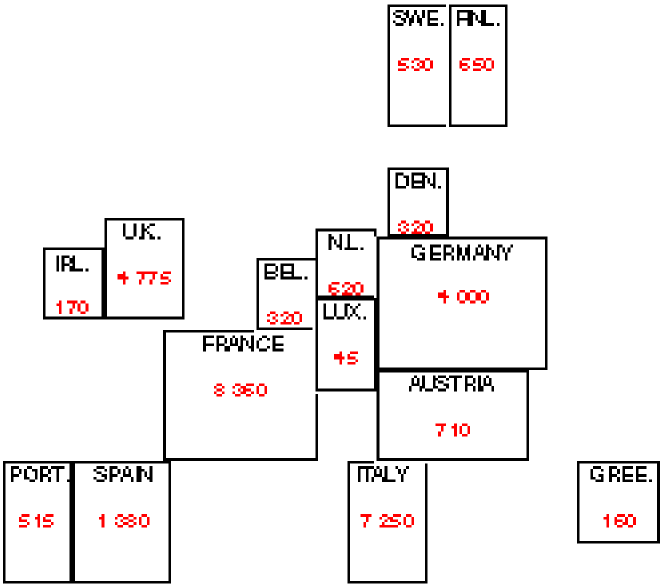

Figure 1. The stock of domestic electric storage water heaters in each EU country (units/1000)

The definition of electric water heater efficiency is complicated by the relationship between the timing and magnitude of the heater power demand and the losses associated with storing hot water until the time of use. Storage water heaters draw less power than instantaneous heaters and the timing of the power demand can be distributed to periods other than those of peak domestic hot water demand; however, they are necessarily less 'efficient' because hot water is left standing in the tank until the time it is drawn-off. There is a connection between the volume of hot water stored, the rated power of the resistance heater and the ability of the water heater to satisfy user demands for hot water. Accordingly, the electric storage water heater efficiency is defined in this analysis as the standing losses (in kWh) per 24 hours as a function of the storage volume capacity and is measured using the European norm CENELEC-HD 500[1].

There is no European-wide limit for the maximum permitted standing losses, although several countries (France, UK, and Germany) have national limits. By comparison with other industrialised countries these national limits are relatively weak, see Figure 2. Analysis of the European market for models of the same storage capacity shows that there is a large spread in both prices,which vary by a factor of 1 to 4, and standing losses, which vary by a factor of 1 to 3. A quarter of the models on the market have standing losses greater than 125% of the market average while only 6% of the models have standing losses less than 75% of the average. In general the more efficient models are sold in the countries with the stricter standing loss limits although the limits in the UK are very weak.

The standing losses for a given volume are most strongly influenced by the quality of the tank insulation. In practice almost all water heaters available on the market use polyurethane foam insulation expanded by a variety of foaming agents that result in minor differences in the foam conductivity. Thus the most important aspect of the design influencing standing losses is the thickness of the insulation. The distribution of the insulation around the tank can also be important as thermal stratification means it is better to position the thickest insulation around the top of the tank which contains the hottest water. A preliminary life cycle cost analysis indicating the average life time cost of a storage water heater as a function of the average insulation thickness is shown in Figure 3. This analysis uses upper estimates of the incremental manufacturing and transportation costs associated with modifying the insulation thickness of a European base case water heater to the specified thickness and thus gives a very conservative estimate of the insulation thickness corresponding to the least life cycle cost. Nonetheless, the results show that the optimal insulation thickness corresponding to the least life cycle cost for a 200 litre water heater operating under a low 'night-time' tariff is 73mm. The current European average is no more than 40mm. When the water heaters are operating under higher 'day-time' tariffs the optimal insulation thickness becomes much higher.

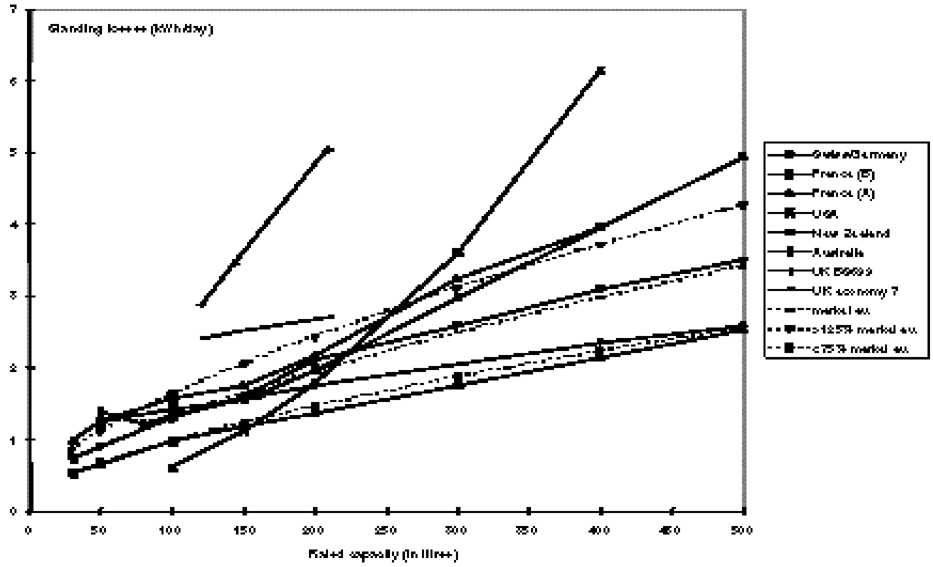

Figure 2. Comparison of the national maximum permitted standing losses with the standing losses of models sold on the European market

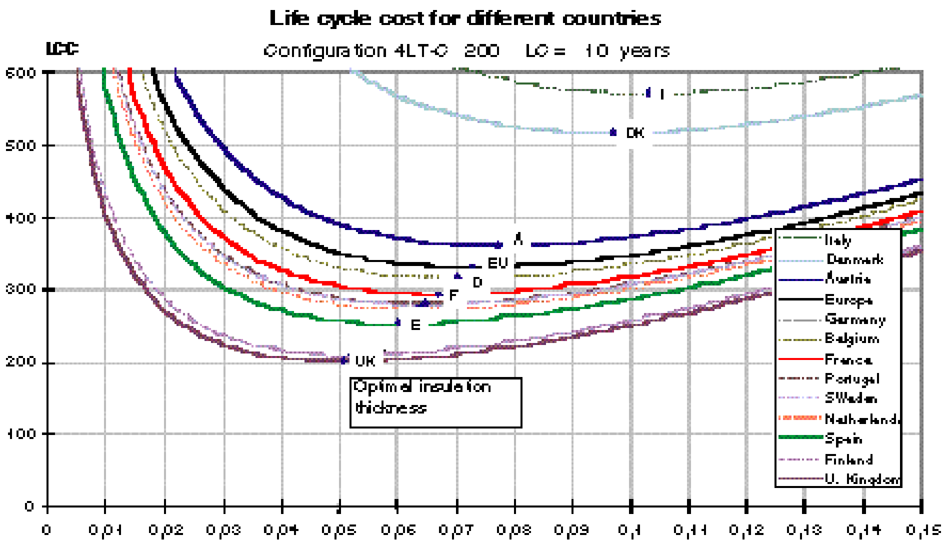

Figure 3. An example of the life cycle cost as a function of the average insulation thickness for domestic electric water heaters in each country

Conclusions

The conclusion of this analysis is that the standing losses of the average European electric storage water heater could be reduced cost effectively by increasing the average insulation thickness to a position consistent with the least life cycle cost. This conservatively ranges from an optimal insulation of 73mm for water heaters with a storage capacity of 200 litres; to 61mm for capacities of 150 litres; to 94mm for those with capacities of only 80 litres (and hence using a single tariff). As many water heaters available in the European market have only 20mm of insulation this measure would lead to significant standing loss savings (~55% for an upgrade of all models to the optimal thickness). Overall EU-wide standing loss cost-effective savings of between 6 and 12TWh/year (depending on modelling assumptions) could be achieved by establishing European wide maximum standing loss limits consistent with the least life cycle cost.

Acknowledgements

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Endnote

[1] This is the European standard based upon the international standard IEC 379 ‘ Methods for measuring the performance of electric storage water-heaters for household purposes ’.