ENERGY DOWN THE DRAIN? IMPROVING DOMESTIC SHOWER EFFICIENCY

A Schumacher Institute Challenge Paper

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The Challenge: Improving sustainability and resilience through domestic energy efficiency measures. In particular, reducing the energy wasted in showering.

1. Domestic hot water energy use and emissions

Climate change and energy security are amongst the greatest challenges for humanity in the coming decades. Climate change is linked to our dependence upon fossil fuels, which when burnt release carbon dioxide (CO2) to the air, strengthening the greenhouse effect and thus contributing to global atmospheric warming. The UK Climate Change Act of 2008 sets targets for reducing carbon emissions by 34% in 2020 and by 80% in 2050, compared to a 1990 baseline.[1] These reductions can be achieved by reducing energy demand while switching to cleaner energy generation through the use of renewables, nuclear power and carbon capture techniques. Energy consumption can be reduced by increasing energy efficiency and using waste energy to drive other processes. Statistics from the Department of Energy and Climate Change (DECC) show that domestic energy use was responsible for 26% of UK energy consumption in 2011, with 60% of this energy being used for space heating and 18% for water heating.[2] Whilst the numbers are similar for CO2 emissions in existing housing, the emissions from hot water use account for a much higher proportion (72%) of carbon emissions in new houses, which generally have better insulation and higher shower use. Annual hot water use in the UK emits around 35 million tonnes of CO2, of which 90% comes from water heating in the home and the remaining 10% from supply and treatment by water companies; this is equivalent to 7.5% of UK carbon emissions.[3]

2. Shower efficiency and design

A significant amount of hot water used in the home is for showering. Contrary to popular belief, showering often uses more water (and therefore more energy) than bathing, mainly because people tend to shower for longer than necessary. A 2011 survey by Unilever found that on average people shower for eight minutes.[4] If everyone in the UK's daily shower took this long using a 9 kW shower unit, the energy consumed would be around 4 GW, the equivalent of four major power stations operating at peak load. Furthermore, around 25% of UK households currently have 'power showers' installed, which can consume twice as much water and energy as an average shower unit, with flow rates of up to 16 L/min.

To date most efforts to save energy in showers have focused on saving water, with energy saving being an added benefit. An educational campaign encourages consumers to change their behaviour and take the 'four minute shower challenge', with egg timers or small alarm clocks in the shower room used to notify the user when they have been showering for four minutes or have used 35 litres of water. By spending less time in the shower, less water is heated and thus less energy is used. This approach has great potential as it is inexpensive to the consumer, but behaviour change on the scale required may prove difficult to achieve. An alternative approach is to modify showerhead designs in order to improve performance. Showerheads are available which aerate the flow, maintaining pressure whilst reducing water consumption. However, rinsing away soap and shampoo requires a certain volume of water; aerating showerheads have been criticised for reducing shower comfort

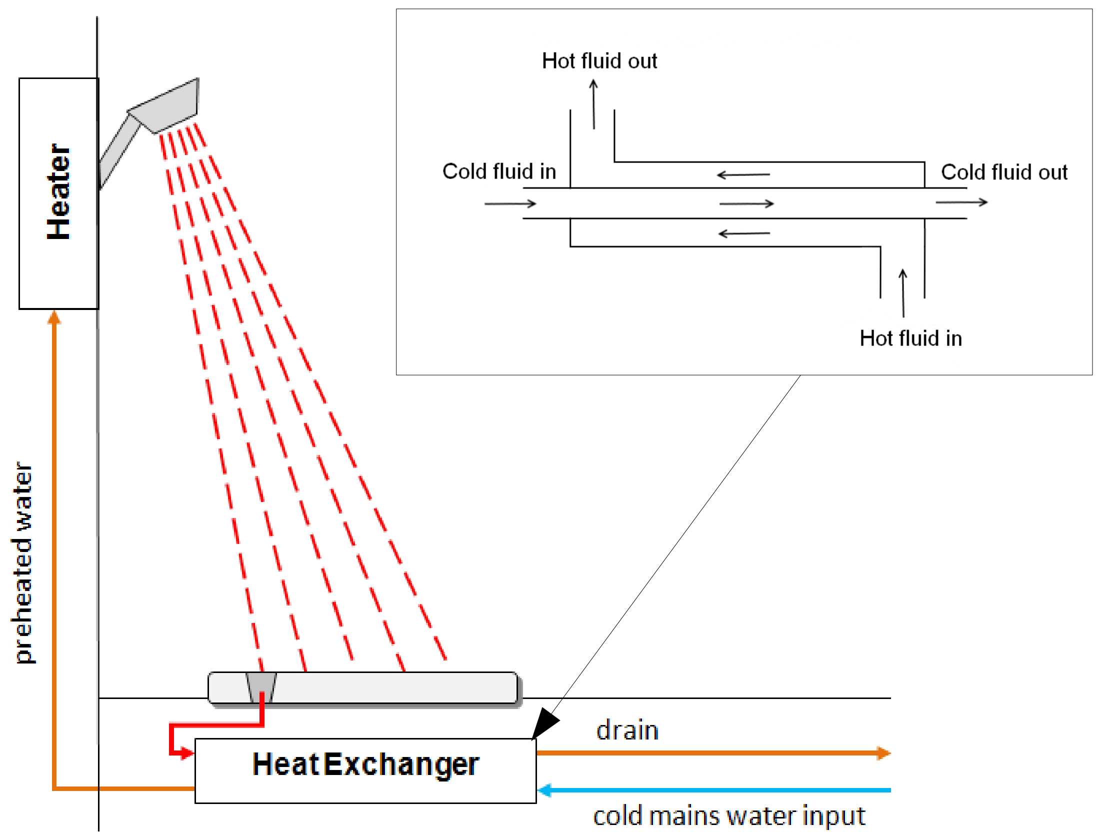
1 DECC (2011) *Carbon Plan*, London: Department of Energy and Climate Change
2 DECC (2012) *Energy consumption in the United Kingdom*, London: Department of Energy and Climate Change
3 Environment Agency (2012) *Quantifying the energy and carbon effects of water saving*, London: EA
4 Unilever UK, (2011) *Unilever UK Sustainable Shower Study*, available online at http://www.unilever.co.uk/aboutus/newsandmedia/2011/sustainableshowerstudy.aspx

and extending shower time. A more recent innovation employs a showerhead design which generates high frequency pulses of water. In the pause between pulses no water flows, resulting in reduced water use. This technique is reportedly non-detrimental to the shower experience.

3. The potential for heat exchangers

The approaches outlined above prioritise saving water, but even if we successfully change shower behaviour so that people shower in under four minutes, we will still be pouring energy down the drain. Tests indicate that hot water leaving the shower still contains around 90% of its thermal energy.[5] Some of this can be recovered through the use of a device called a heat exchanger, which is placed beneath the shower tray. As shown in Figure 1, a heat exchanger works by channeling hot waste water parallel to cold input water, so that heat can be transferred between the flows. This simply requires a conductive heat transfer surface separating the two channels. If the hot water flows in the opposite direction to the cold water through an extended channel, the cold water will approach the starting temperature of the hot water as it leaves the exchanger. This means cold water can be heated using shower waste water before it enters the shower heating unit.

Figure 1: Heat exchanger under shower tray.
Inset: the basic operation of a heat exchanger



Heat exchangers are most effective when the heat transfer surface area is maximised and the fluid flows in each channel are highly turbulent. This can be attained by making the channels long and narrow with plenty of bends so that the fluid is continuously mixed, enabling a high degree of heat transfer. However this increases the pressure required to push water through the channels, meaning

5 In a 39°C shower water was recorded leaving the shower on average only 2.8°C lower than it entered.

that a pump is then required to avoid a backlog of water filling the shower tray.

Once an efficient exchanger layout has been developed, the main problem becomes fouling in the heat exchanger. Fouling is the build-up of unwanted material on surfaces in the exchanger, causing major drops in efficiency. A heat exchanger in the shower setting must be able to cope with the hair, soap, skin and dirt present in shower waste water; the use of suitable construction materials can mitigate the effects of these contaminants.

4. Investigating shower heat exchanger designs

In 2011/12 a research project at the University of Bristol investigated building a heat exchanger for use in showers.[6] It was found that a simple heat exchanger design directly saved 37% of the energy used by a 9.8 kW shower unit. Additional modelling indicated that an exchanger approaching the size of the shower tray would be able to recover as much as 48% of the energy used in the shower. Although the design was not particularly elegant, requiring a pump and large metal plates to seal the channels, it was estimated that it would only cost around £115 per unit to produce.

With regard to the effects of fouling it was found that shower waste water does not present a problem if suitable construction materials such as copper and polypropylene are used. The major challenge to the longevity of the design arose from calcium carbonate (limescale) precipitation. In hard water supply areas, limescale sticks to heating and cooling surfaces, reducing the efficiency of heat transfer and increasing the pressure of the system. After a number of months it is conceivable that the exchanger would fail due to the increased load on the pump. At present the most practical solution to limescale is a regular cleaning program with limescale removal products or vinegar. Further research could explore the use of anti-fouling coatings.

The simple prototype tested in this project indicated considerable scope for energy saving in showers. The key to future success lies in finding the optimal balance between effectiveness, durability and cost. A family of four who shower daily for 8 minutes each using a 9.8 kW shower will spend around £343 on heating water for their shower needs (at 18p per kWh). By saving 48% of the energy used, the family could save up to £165 per year. This provides a persuasive argument for the use of a heat exchanger in showers, since the payback time on the initial investment can be very short. As it is possible to create shower heat exchangers for a fraction of the price of the yearly shower bill, bringing considerable savings for the consumer, it may be that a mass market can be developed for such products.

5. The future

At the present time more research is needed, both academic and commercial. A number of heat exchanger products are already appearing on the market, but so far they are expensive and under-publicized; a straight-forward DIY installation process coupled to a cost-effective design and an effective marketing strategy could encourage more widespread uptake by consumers. One effective strategy may be to engage journalists with the issues, so that the information reaches a wider audience, encouraging them to consider energy efficiency when taking their next shower. Research into an integrated shower-exchanger unit may also be beneficial, as this would further reduce the complexity of installing systems. In the meantime, there are opportunities for green enthusiasts to build their own, and indeed some are by placing copper pipe inside a larger waste water channel.

The opportunity to educate users at the installation stage should not be missed; with a heat exchanger, it is relatively easy to explain how energy is being saved. Improving consumers' understanding of energy issues can encourage more energy-efficient behaviour elsewhere in the

6 Hinchliffe, D & Corrigan, S (2012) *Radical Improvements in The Efficiency of Showers.* Bristol University: Bristol, UK.

home while helping to promote domestic heat exchanger technology though word of mouth. It should be noted, however, that the efficiency savings possible with shower heat exchangers may not necessarily significantly reduce annual household carbon emissions. This is due to so-called 'rebound effects'; users may begin to shower for longer in the knowledge that they aren't using as much energy, reducing the energy savings potential and leading to increases in water consumption. Users should be made aware of this possibility and encouraged to shower for the same length of time or less than before the installation, perhaps in conjunction with a water saving showerhead.

Whilst showers present an ideal scenario for using heat exchangers as they have equal inflow and outflow rates, they can also be fitted to other household appliances such as washing machines. Heat exchangers have already been used to make dishwashers more efficient, and it is possible to link domestic appliances so that the heat recovered from one is used in another. Looking to the global scale, if we assume that each day around two billion people shower for 8 minutes, saving half the energy used could release enough energy to power the entire UK! Fully realising the great potential of heat exchangers will require an interdisciplinary approach: we must think about effective resource use while applying our physical and chemical engineering skills to develop efficient and reliable products. Effective marketing and communication will be needed to get the exchangers into homes. We've heard of showers using grey water, now it's time our showers started using green water too.

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