

Water and energy conservation through efficient design.

by Oliver Sylvester-Bradley

Introduction

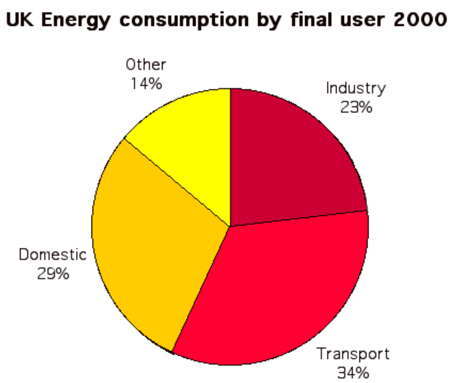
In a sustainable society the efficient use of resources is essential. Everyday we waste huge amounts of energy and natural resources through inefficient out-dated designs and technologies. This essay discusses the fundamental importance of efficiency and uses the example of domestic hot water heating to demonstrate the potential of alternative technologies and efficient design. It also questions the practicality of current regulations with respect to improving efficiency.

Efficiency demands innovation

It is estimated that £5billion worth of energy is wasted annually in the UK (Orton E. 2002) through the use of inefficient technology. It has also been stated that the most cost-effective and environmentally benign source of energy is greater efficiency (WCED 1987). If we are going to progress to the levels of efficiency required in order to achieve a sustainable society current solutions, that provide results by employing inefficient technologies, can no longer be considered viable solutions. Mandatory energy efficiency and consumption standards for equipment are perhaps the most powerful and effective tools in promoting energy efficiency (WCED 1987) by enforcing minimum standards, but the development and promotion of more efficient design surely offers a greater potential. Successful innovation is the source of all progress towards greater efficiency and should be recognised and encouraged as such, accelerating our potential to be truly efficient through the application of improved design.

Heating water in the UK

To illustrate the potential of improved design I will use the example of domestic water heating in the UK. Of the 232.6mtoe consumed annually in the UK 29% is for domestic use. Each household consumes on average 23,000Kwh/year of which 84% is for heating and hot water, the equivalent of 19,320Kwh per household per year (DTI 2002).



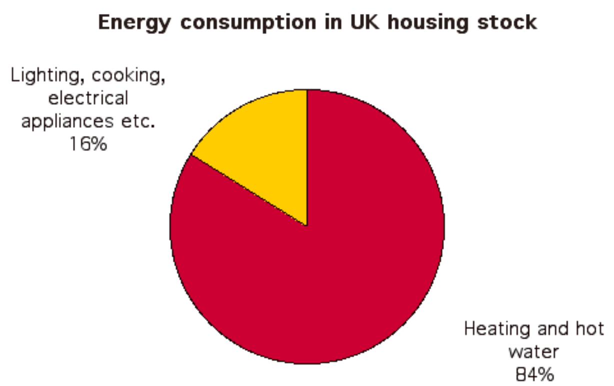


Figure 1: UK Energy Consumption
Total UK energy consumption: 232.6mtoe (other uses include: Agriculture, Commerce, Public Admin, etc.)
Average household energy consumption for heating and hot water: 19,320Kwh per year.
All data from the Digest of United Kingdom Energy Statistics 2001 DTI

The standard tank-tree hot water heating system is very inefficient returning only 50.3% of input energy in a low use situation (Wiehagen J. 2002). My calculations (see Appendix) show that at least 236 million litres of water and over 10.8GWh of energy are wasted in the UK every year by simply waiting for the hot tap to run warm. The basic requirements of delivering suitable volumes of hot water as, when and where it is needed, with the minimum energy consumption are not being met by current solutions due to the inadequacies of current designs. In order to achieve maximum efficiencies the problem needs re-addressing entirely taking into account every practical alternative solution.

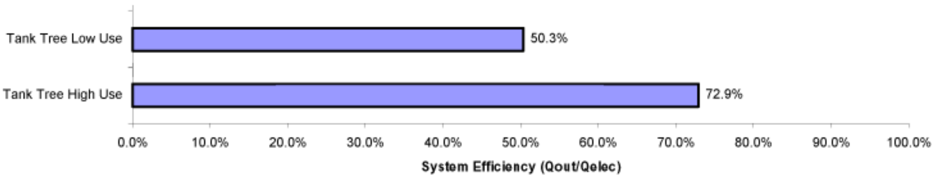


Figure 2:
Annual energy delivered at outlets for low (106L/day) and high use(287L/day) of a conventional tank-tree hot water system. (Wiehagen J. 2002)

Alternative technologies

One obvious solution is to heat the water only when it is actually needed using a 'demand' type boiler. Investigations show that electrical energy savings of demand heaters with parallel piping systems compared with the standard 'tank-tree' system are 34% for a low-use home (106 litres per day) and 14% for a high-use home (287 litres per day) (Wiehagen J. 2002). Such systems are also reported to be less expensive to install and operate than conventional systems but their use in UK new housing is virtually non-existent.

Removing the need to distribute hot water entirely by using demand boilers where the water is needed offers even greater potential for efficiency because lower delivery temperatures are required. Simulations show that system efficiencies are nearly 100% and annual energy consumption can be reduced by almost 50% for the low-use home and 28% for the high-use home in comparison with the standard 'tank-tree' system, which translate into vast nation-wide energy savings (Wiehagen J. 2002). Solar water heating could provide for 50% (STA 2002) of the required water heating capacity in the UK. Despite obvious limitations, potential energy savings from solar water heating systems make them a fundamental consideration in any UK design. Solar systems also seem perfectly suited to use in conjunction with localised demand type boilers in order to minimise primary energy consumption (Fig.3), showing the potential to radically reduce primary energy consumption by up to 75% (see Appendix).

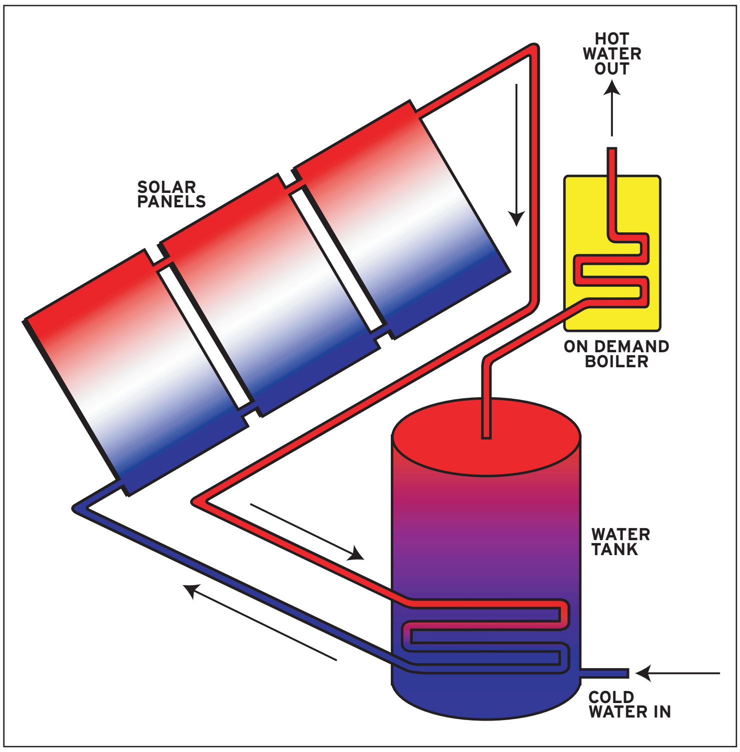


Figure 3:
Minimising energy consumption by combining solar water heating and 'on-demand' boilers.

Figure 4:
A typical electric demand type boiler.

Another excellent solution, and a prime example of the inadequate transfer and dissemination of information contributing to national efficiencies, is the condensing boiler which has had an extremely slow take up ever since first launched in 1980 ‘due to a number of misconceptions and a general lack of awareness…’ (BRE 2002). A condensing boiler will always have a better operating efficiency than a conventional non-condensing one, due to its larger and more efficient heat exchanger. If everyone in the UK with gas central heating installed a condensing boiler, we would cut CO2 emissions by 18.6 million tones, saving enough energy to power four million homes for a year (DDC 2002). Despite conclusive evidence that condensing boilers can save huge amounts of energy they are still taxed at 17.5%, this issue should be re-addressed immediately to encourage the use of this efficient design.

In domestic situations CHP returns marginal benefits due to the fluctuations in demand for hot water however, because of the electricity supply, primary energy consumption is reduced throughout the year (Kato T. 2001). The Energy Saving Trusts’ ‘realistic consideration’ is that 700,000 dCHP units will be in use in the UK by 2010 offering important national energy savings however, careful planning and education will be necessary if this valuable technology is not to suffer the same fate as the condensing boiler. Dense population housing (ie flats/hospitals/hotels) offers far greater potential for CHP due to efficiencies of scale and predictability of demand. A recent £267,000 investment in CHP for flats in St. Pancras, London is not likely to be paid back for 7 years but will incur an annual primary energy saving of 650,000KWh and a 20% reduction in CO2 emissions for the site (Doggett A. 2002). Such savings are essential to help meet the recommended reduction of greenhouse gas emissions but also illustrate the type of location specific design that is necessary in order to achieve greater efficiency.

Retrofiting efficiency

It is bad practice to think we can ‘add-on’ efficiency to inefficient designs, we may help save energy but we will never solve the problem (Fig. 5). However, considering that there are roughly 1.3 million boilers in the UK of which 80% are old and inefficient (Gasforce 2002), there is vast scope for improvements via ‘retrofit’ technologies. Burner management units and flue heat economisers, which are largely unknown to the general public, can reduce fuel bills 15-20% by reducing burn cycles and heat loss on conventional systems. These are minimal investment technologies which should not only be widely publicised but also subsidised to assist national uptake. A burner management unit, which is just one example of a multitude of retrofit innovations, costs only £650 fitted and can pay back it’s cost in 6 months in a high use situation.

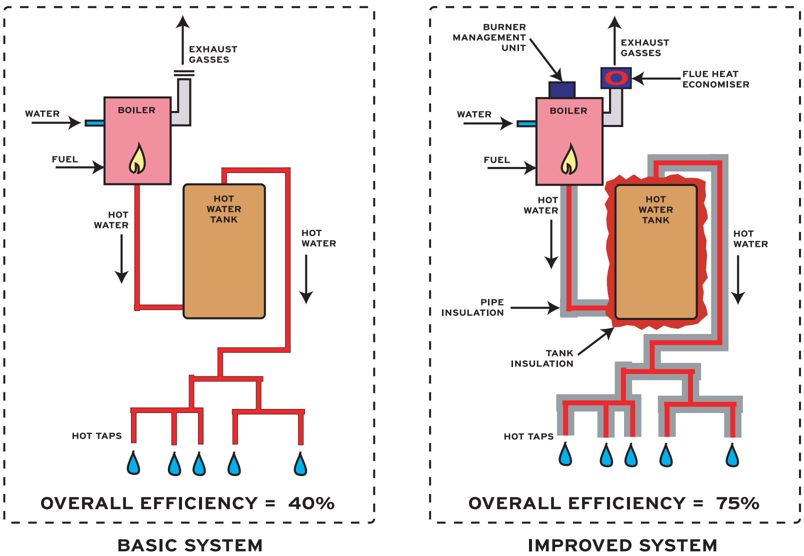


Figure 5:
Retrofiting efficiency is an inefficient process that will never achieve the desired result, it can save but never solve. “Relying on [retrofit] eco-efficiency to save the environment will in fact achieve the opposite - it will let industry finish off everything quietly, persistently, and completely...” (McDonough 2002)
What we need is efficient design.

It is also possible to reduce water heating costs by combusting waste, capturing and combusting waste methane, using underground heat sinks and several other innovative technologies. No single design will provide the perfect solution and in order to achieve maximum efficiencies it is necessary to consider each situation and apply the most suitable efficient design. From just the range of solutions presented here it is clear to see that by applying the most efficient designs we could radically reduce national energy consumption for hot water heating.

Regulations & Standards

It is important to remember that the longevity of UK housing stock means that todays' building standards affect the countries efficiencies and emissions for the next 100 years.

The latest changes to UK building regulations (Part L), which came into effect on the 1st of April 2002, insist that insulation, pumped systems, timing and thermostatic controls are now obligatory however, as is typical, these regulations lag way behind 'best practice' (Fig 6). Not only are they so confusing that their agency felt it necessary to commission a set of explanations from a third party but they lack the necessary vision required to inspire design efficiency. David Olivier (2001) from the Association for the Conservation of Energy considers the updated regulations to be a 'missed opportunity' to improve the quality of new housing in England and Wales, recommending that we should 'set higher, but simpler standards; Actively disseminate successful techniques and technologies; give builders incentives to guarantee maximum heating bills.' Designers at XCO2 state clearly 'Incremental improvements to building codes are not fast enough and savings through retrofit are limited' (XCO2 2002). In a separate report Bill Bordass (2001) recommends that 'there must be direct feedback from performance of real buildings into regulations.' As they stand the regulations themselves are inherently inefficient due to unnecessary complications and a stagnant revision process. The adoption of 'best practice' and 'advanced' design, a largely ignored and exclusive field, should be rewarded accordingly in order to assimilate the need for greater efficiency into our design and building mentality.

Progress has been made by the SEDBUK organisation (Seasonal Efficiency of Domestic Boilers in the UK) which classifies boilers using the recognised A-G rating scheme and this will undoubtedly improve national efficiencies but it still operates as a minimum rather than a maximum standard, which is inherently inefficient. The overall standard of new British homes is so low it is jeopardising our ability to reach climate change targets in 2010 and beyond (Olivier D. 2001).

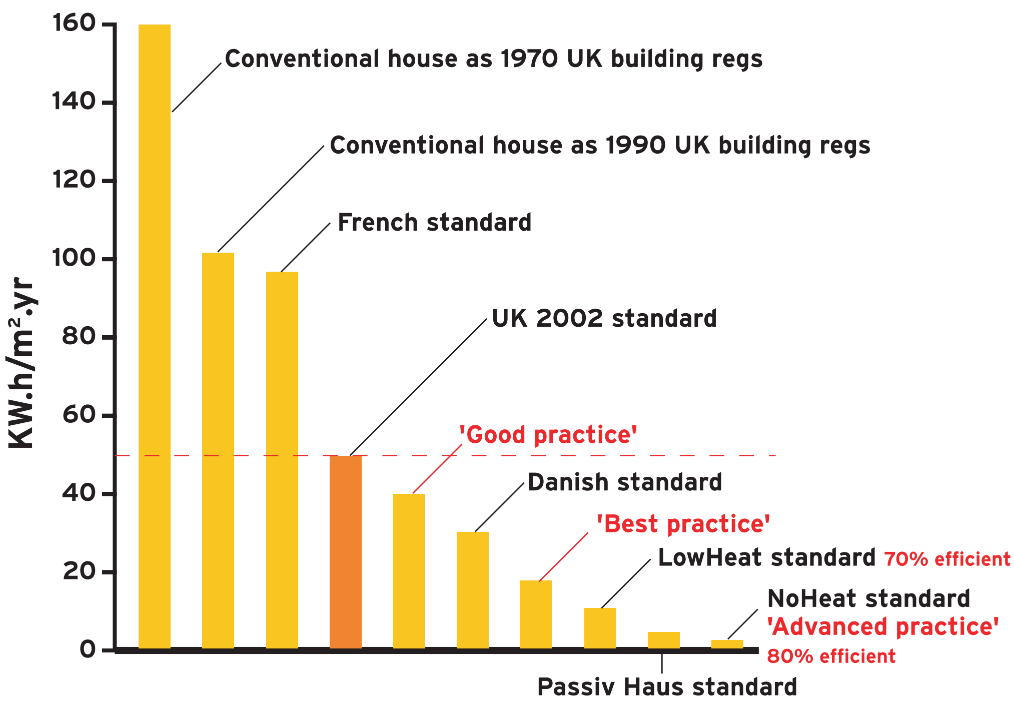


Figure 6:
Energy consumed for heating houses built to different standards. Current (theoretical) building standards have improved dramatically but, is it actually encouraging efficiency and efficient design to set minimum standards which are so much lower than currently attainable 'advanced' standards?

STANDARD	HEAT ENERGY USE	BUILD COST	LIFE TIME HEAT ENERGY COST	OVERALL SAVINGS
Building regs	50 KW.h/m².yr	£100,000	£28,000	- - -
Good Practice	40 KW.h/m².yr	£101,000 (+1%)	£22,400	£4,600
Best Practice	20 KW.h/m².yr	£108,000 (+8%)	£11,200	£8,800
Adv. Practice	4 KW.h/m².yr	£120,000 (+20%)	£2,240	£5,760

Figure 7:
Comparing the amount of money spent on heating over the lifetime of a house with the extra building costs necessary to achieve greater standards (and hence lower heating costs) we see that current building standards are both uneconomical and inefficient.

Assumptions:
1KWh=7p
80m² house costs £100,000 to build
Energy prices stay constant and houses last for 100 years
Additional benefits:
Huge reduction in primary energy consumption + savings in CO² emissions
Sources:
Insulation for sustainability XCO2, Energy Efficiency Standards - For new and existing dwellings HEEBPP

Conclusion

Efficient design is a prerequisite of sustainable development and a governing factor of our ability to reduce emissions. Heating space and water in the UK shows enormous potential for savings through efficiency. There are a several proven alternative technologies offering improved efficiencies for water heating which should be utilised immediately in order to reduce national energy consumption. Current regulations are failing to encourage the levels of efficiency required to meet climate change targets in 2010 and beyond. In order to promote efficient design and the widespread use of energy efficient products I recommend that regulations should:

- Specify maximum rather than minimum standards.
- Reward the design and use of efficient technologies (eg: via TAX breaks).
- Allow constant feedback to make them truly efficient themselves.

Improving efficiency in general requires urgent positive action: ‘We gain nothing by delay’(Oreszczyn T. 2002).

Limitations of this essay and potential for further research and development

This essay examines the vast subject of energy efficiency and uses the example of hot water heating systems to demonstrate the huge potential of efficient design. The examples of water and energy wasted by waiting for the hot tap to run warm and the potential for linking solar powered water heaters with distributed tankless heaters demonstrate one minute aspect of the benefits of efficient design. (This area requires further research and quantative analysis comparing overall costs vs efficiencies in order to prove its’ potential conclusively.) This methodology is obviously applicable to many more systems and, I believe, could be developed indefinitely in order to achieve valuable improvements in efficiencies world-wide. Although no essay on efficiency would be complete without mention of regulations it was impossible to discuss the subject in enough detail within the parameters of this essay and I strongly recommend further development in this area, specifically looking at: incentives for the use of efficient design, the dissemination of information regarding efficient technology, the marketing potential of efficient technology, the appropriate and immediate use of tax-cuts, grants and incentives to promote efficiency and the development of active regulations which evolve as does the technology and problems they are supposed to regulate.

Appendix

Wasted water and energy from hot water 'run-off'

Average domestic water usage in the UK is roughly 150L/person/day (Thornton 2002) of this at least 40% (60L) is used hot. Taking an average of 2 Litres from my data for wasted water run-off (before the hot tap runs warm) and assuming that this is done twice daily by everyone in the UK (taken as 59M people) we can calculate that 236M litres (2 x 2 x 59M) of hot water is wasted daily in the UK. The energy required to heat 236M litres of water from 9.4°C (average UK temp source DTI 2002) to 49°C (required temp. of hot water) can be calculated as follows:

39.6 x 236M = 9345.6M kg-calories

9345.6M x 1.163 x 10^{-3} = 10.8M KWh or 10.8GWh

This calculation assumes 100% efficiency of water heating and is a very rough figure due to insufficient data, errors in measuring volumes of wasted water and assumptions about the frequency of using a hot tap, however the principal is sound and the experiment could be repeated in greater detail to obtain more accurate results.

Wasted water: Measurements of volume (Litres) of water run-off before hot taps run warm:

House 1	1.4	1.5	1.3	2
House 2	2	7	5.5	2.5
House 3	1	2	0.5	3
House 4	2.5	3	1	0.5
House 5	2.5	1	3	0.5
House 6	1	0.5	0.25	
House 7	2.5	3	4	4
House 8	1	1.5	1.3	
House 9	2	1.5		
House 10	3.5	2.2	2	1.7
House 11	1.5	0.5	1.2	
House 12	2.0	1.8	1.7	2.5
House 13	1.5	1.3	1.5	1.5
House 14	2.2	1.8	1.7	2
House 15	1.8	1.9	2	2
House 16	2.5	1	0.5	
House 17	0.5	1	2	

TOTAL for 61 taps: 115.55 Average = 1.89 Litres

Solar water heating used in conjunction with localised demand type boilers

Solar water heating could reduce average annual household water heating energy consumption by 50% and localised demand type boilers that return 100% efficiency instead of 50% (for low use of a conventional tank-tree system) could reduce consumption by a further 50%. If every UK household used this system domestic UK energy consumption for heating and hot water could possibly be reduced from 477,204Million KWh/year (19,320Kwh/y x 24.7M houses) to 119,301Million KWh/year, a 75% saving.

This calculation assumes solar and demand heaters could also be used for space heating and that every house in the UK is appropriate for solar water heating and is therefore very basic, however the principal is sound and the calculation could be refined to obtain more accurate results.

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