Energy Options

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Introduction
Energy is a major contributor to carbon emissions. Measures to reduce emissions are best considered under 3 Basic Divisions: Save, Supply and Store.
The target groups can be divided into:
Individual households
Schools, Churches, Commercial premises and Industry
Authorities: Town/Parish, Unitary authority and national.
However principles stay the same.

Save
The national energy efficiency standards for new build and new homes is set by HMG. Thermal efficiency (measured in U values) is currently 1.4 Wm2K for windows, 0.18 for walls, 0.13 for floors and 0.15 for roofs . However there is no reason why individuals cannot build to higher standards, particularly if they are fitting a heat pump which qualifies for the renewable heat initiative (RHI). Passive House (Passivhaus in German) is a voluntary standard for energy efficiency that is designed to reduce the carbon footprint of a building. *https://en.wikipedia.org/wiki/Passive_house*

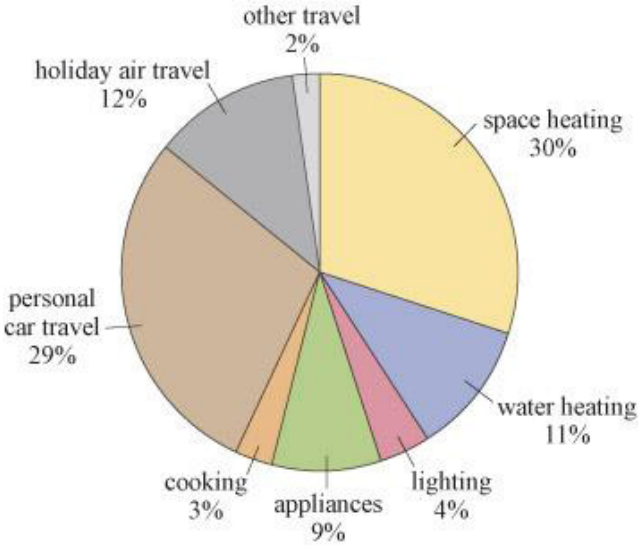
There is considerable scope to improve the energy efficiency standards for existing homes. A variety of measures are available of varying complexity with different pay-back times.
Thus fitting draft excluders, curtains or shutters for single-glazed windows, lagging pipes and hot water cylinders, and loft Insulation has a pay-back time of 2 years or less.
Prior to 1930 houses were of solid brick construction. After 1995 cavity walls were filled with insulating material. Insulation can therefore be installed into suitable houses built between 1930-1995. ie those built with empty cavity walls that don't have problems with damp (Payback time <5 years).
External and internal cladding can also be used for any property, but particularly for those of solid wall construction (28% of housing stock)
Internal is cheaper than external but reduces floor space (Pay back 17.5 years)
External cladding has a pay-back time of 23 years.
Single glazed windows have a U value of 4.8. Secondary glazing 2.9-3.4.
Double glazing varies from 1.2-3.7 depending on the thickness of glass, the width of the air gap and the whether air or argon gas is used. Triple glazing has a U value of 1.0 or less.
Double and triple glazing has a longer pay-back for existing build (>30 years).

For a more detailed analysis, see costs and benefits of retrofitting houses to reduce heatloss: http://www.marlowenergygroup.com/post/costs-and-benefits-of-retro-fitting-houses-to-reduce-heat-loss

Fig. 1 Eco house with triple glazed doors and windows. Photovoltaic solar panels built into roof.

Supply

In assessing the direct carbon emissions of the average UK individual, where “direct” indicates energy and transport use only: roughly 29% comes from personal car travel, 14% from other travel including holidays, 16% from cooking lighting and appliances, and 11% from water heating. However the biggest contributor is space heating (30%).



In the UK, gas boilers are mainly used for water and space heating, since gas is currently much cheaper than electricity. However this is set to change, as Government strategy is to replace gas with electricity. For example no gas boilers will be fitted to new homes in the UK from 2025. Initially these will be replaced by low carbon heating systems such as heat pumps. Eventually it is envisaged that homes will be supplied with hydrogen gas as combustion of hydrogen produces no carbon dioxide. However hydrogen is currently produced mainly from fossil fuels. In an ideal world hydrogen will be generated exclusively by electrolysis of H20 using excess grid capacity on days when there is abundant renewable energy.

Fig 2. Direction carbon emissions. Average UK individiual. Source: DTI

Solar Panels

Meanwhile there are a number of technologies that individual householders can install to reduce their gas or electricity bills, and hence their carbon emissions. The best known are solar thermal, used to heat water only, and photovoltaic (PV) panels which converts solar energy into electricity. This can be used for any energy requirement including charging a renewable vehicle, hence saving on petrol or diesel expenditure. The pay back time for PV panels depends upon whether or not it is part of a group installation, and also on any available subsidies. The Government’s feed in tariff for new PV installations was discontinued in April 2019. Since then energy companies are required to offer an export payment, but not all have done so, or they have made it conditional on installing the system. However some companies (eg Octopus Energy) do offer around 5.6p/Kwhr, but insist on a smart meter. DF has calculated a pay-back time of 11.5 years for a group installation of PV panels with an export payment.
A survey by Marlow Energy Group showed that only 75 houses in Marlow have a PV installation, and only 39 have a solar thermal installation, so there is huge scope for improvement. Solar thermal (liquid filled flat plate or evacuated tube) is a qualifying technology for the RHI, but only for domestic hot water, not space heating and not swimming pools.

Heat Pumps

An alternative way of providing heat is to install a heat pump. These absorb heat from a cold space (the source) and release it to a warmer one (the sink), like a fridge in reverse. The source can be outside air (Air Source Heat Pump; ASHP), the ground (GSHP) or water in a river or lake (WSHP). The sink can be the air in a room, a swimming pool, under floor heating, radiators or even domestic hot water, but the efficiency of the heat pump (The Coefficient of Performance or COP) depends inversely upon the temperature difference between the source and the sink. So heat pumps work best for low temperature systems such as swimming pools, under floor heating or low temperature radiators which operate around 40C. If heat pumps are used to heat domestic water, then an internal WSHP will need to be fitted in tandem to raise the water temperature to the required level (60C). Alternatively a heat pump can preheat the water in a hybrid hot water system.

ASHPs are most efficient in the summer when the outside air temperature is closer to the delivered temperature, and less efficient in winter. The source temperature of GSHPs and WSHPs show less seasonal variation and are therefore more efficient than ASHPs, but they are also more expensive to install. A GSHP for a typical dwelling involves 100 metres of pipework buried in loops a metre underground. Exact prices are difficult to calculate as it depends upon the distance from the house, and the type of soil. Light sandy soils need a greater length of pipework. But a rough comparison is

Fig. 3 Air source heat pump linked to underfloor heating system

£10-15K for an ASHP versus £40K for a GSHP. Government subsidies are available via the Renewable Heat Initiative (RHI) which is paid on an annual basis, but the system has to be installed by a company which is MCS certified (Microgeneration Certification Scheme). DF has calculated a pay back time of 10 years for an ASHP with RHI payments.
The cost-effectiveness of the technology also depends on whether the house is new build or existing build. Thus an ASHP can be retrofitted to an existing building to warm the air internally at relatively low cost. Some ASHPs can also operate in reverse during the summer and function like air conditioners. However if heat pumps are used to heat the water in radiators, then it is not going to be cost effective if the existing high temperature system needs replacing with larger low temperature radiators. As a general principle GSHPs are usually fitted to new buildings or retrofitted to large premises such as businesses or schools where they are more cost-effective. One study showed that the pay-back time for industrial heat pumps was only 2 years.

Wind turbines
Wind turbines operate well in the winter, and are easy to scale up, so wind farms are the main renewable energy source for the National grid and have largely replaced coal-fired power stations. In the UK there has been political and local resistance to on-shore wind farms, so most wind energy comes from off-shore wind which initially was three times the price. However prices are falling, opposition is decreasing, and on-shore wind is now the cheapest form of energy available (<£50 per MWh, or 5p/kWh).

Most wind farms use 3-bladed horizontal-axis wind turbines, but the vortex created by the blades creates a noise. Vertical-axis wind turbines generate less power, but they are quieter, and don't need to rotate to face the wind for maximum efficiency. They are particularly useful when built into a structure that does not allow rotational movement. Smaller wind turbines (<100 kW) are available for commercial premises, but are more often installed in remote locations that are off-grid. Hybrid solar and wind-powered units are also used for traffic signage, particularly in rural areas without a mains connection point.

A stand-alone 5kW wind turbine would be suitable for a domestic installation, and costs £20-25K. However installation costs can amount to another 10K. Output is around 9000kWh per annum but depends upon the location and local topography. This is three times more expensive than PV panels where an investment of £4000 can generate 3500kWh annually.

Fig. 4 Wind turbine

Storage
One of the common criticisms of renewables is that they are intermittent, and don't always work when you need them most (At night or during the winter). For individual householders, a lot of the renewable energy generated is wasted as it flows back to the grid when the system is working at maximum capacity. These problems can be overcome firstly by using a variety or different renewable technologies, and secondly by installing a system that

stores energy until it is needed.

We don't normally think of a hot water cylinder as an energy storage system and it may be unnecessary as it is possible to provide hot water using a gas boiler without any cylinder. However if you are using solar power, then the cylinder becomes an energy storage system that provides hot water even after the sun goes down. Similarly heat storage radiators can be topped up during the day, using an ASHP for example, and continue working in the dark when it is most needed.
A more versatile system is battery storage as rechargeable batteries can be used for any electrical appliance, including charging an electrical vehicle. Simple rechargeable storage batteries start at £4K, but smart batteries, that can be combined to produce a mini power plant, are more expensive.
Some electric vehicles can themselves be used as a storage system By charging the car battery during the day, the vehicle can then be used as a power source at night. This technology works with the Nissan Leaf but not with Tesla cars.

Fig. 5 Tesla Charing Unit & Tesla Model 3 car

Tesla do provide their own power-pack (200kWh rechargeable lithium-ion battery) at a cost of £8K. This allows the car to be driven during the day and re-charged at night. However a Tesla power pack will only provide one third of the total capacity of the Model 3 car battery, so additional charging may be needed depending upon the average daily mileage. If cars need to be charged from the Grid on a regular basis, then it makes more sense to charge overnight when demand is low and a cheaper tariff is available.

As systems are scaled up, larger energy storage measures become feasible. For example the nuclear industry use excess capacity to compress air in underground caves. In North Africa solar power is used to heat salt which is used as an energy source at night. The National Grid use excess capacity to pump water up hill and then release the water at times of peak demand (Pumped hydro). Large banks of storage batteries could also be used at a local level if householders were allowed to combine their renewable energy to create their own micro-grids and store the excess capacity. Unfortunately this is currently prohibited by law as only licensed energy companies are allowed to sell power. Power to People are trying to get this law amended through the Parliamentary process.