An Energy Primer for Suburbia

Frank Thompson

Some thoughts on energy and future energy consumption .

Energy in a Nutshell

World energy flow is depicted on the diagram overleaf and for many millennia there was a balance between incoming energy from the sun (1.7 x 10^{17} Watts) and that leaving through either direct reflection or via infra red (IR) radiation from a "hot" earth. The diagram was in a simplified form with all RED BOXES and LINES removed.

At first, any energy that humans used presented no problems as only the RENEWABLE ENERGY box was included; plants for food, timber for burning or construction and animals for transportation or doing work or food products. It was a sustainable existence for mankind and nature.

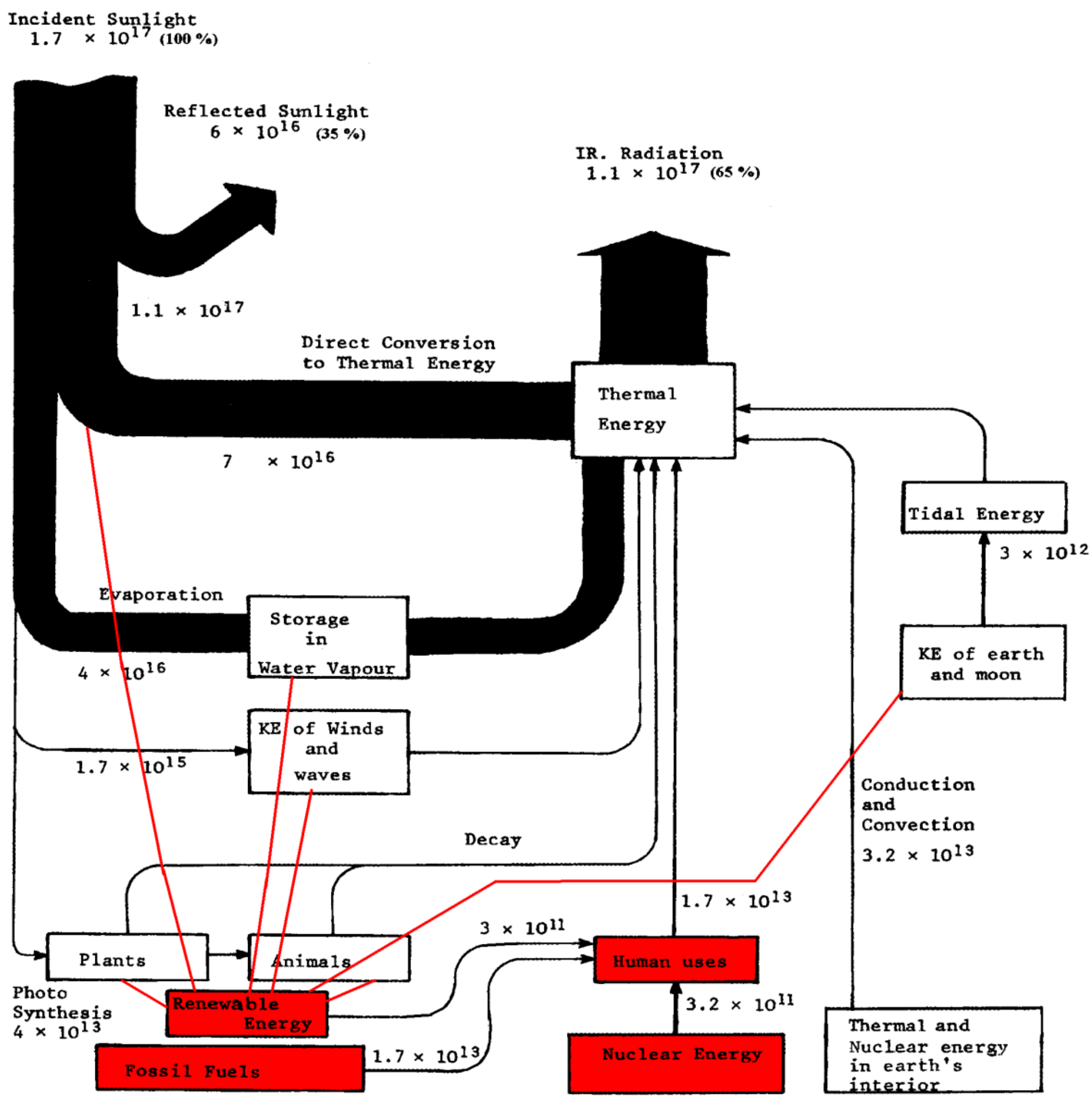
Civilizations grew up under this regime – Egyptians, Chinese, Incas, Greeks, etc -with cultural and social developments occurring. Immense feats of construction were carried out – Pyramids, Wall of China, Machu Picchu, Parthanon – not to mention the construction of cities and towns with many magnificent state buildings, palaces, homes and places of worship throughout the world.

Progress of time showed that wind and water power could be used as sources of energy and drying commodities in sunlight has been used from time immemorial.

Nineteenth century life has led to the box FOSSIL FUEL being added to the diagram and over these recent years the increasing use of fossil fuels (coal, oil and gas) has changed the way the earth looses its heat. Since the gas carbon dioxide, CO_2 a by-product of burning fuel, interacts with the IR emitted radiation the so-called greenhouse effect has arisen and the earth is getting hotter. If the ice caps melt at the North and South Poles then the Reflected Sunlight (6 x 10^{16} Watts on the diagram) becomes less and hence this will further add to global warming. Thus we see that in the last few decades the earth has been driven into severe imbalance.

The energy box NUCLEAR ENERGY has arisen since the late 1950's and, as yet, no one has developed a safe strategy of containing radioactive nuclear waste. There is no CO_2 involved with nuclear power and therefore this form of energy looks to be a likely saviour for the environment. However, other threats such as radioactive material finding its way into the hands of terrorists could be equally damaging to the survival of the human race.

The long term future **has** to rely on RENEWABLE ENERGY as fossil and nuclear fuels are only a finite resource and will eventually run out. The worry is that the environment is being so badly damaged that the earth will not be capable of supporting plant, animal and human life as it did in pre-twentieth century times.



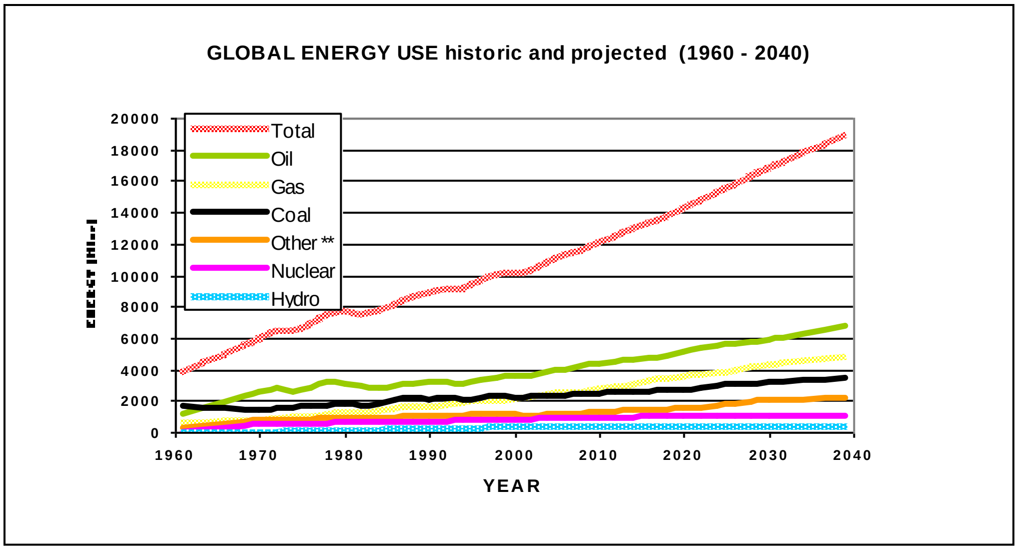
The earth's energy flows, with the details of the exchange of radiation between the surface and the atmosphere omitted

(The numbers given are in Watts and are rounded up to one decimal place)

Figure 1.1 Energy pathways for the sun-earth system

I Global Issues

One does not have to go too far back in history, say to a pre-industrial world, to find that society was totally dependant on energy from the sun. The energy flow diagram, Figure 1.1, shows that, without using fossil or nuclear fuels, an energy balance was achieved between incident and re-radiated energy. Complications arose with the use of fossil fuels over the so called “greenhouse effect”. Some of the outgoing infra-red IR radiation is now redirected back to earth and a balance can only realised if the earth gets hotter. Humanity has an insatiable appetite for energy, as Figure 1.2 shows, and hence global warming is set to continue for several decades to come.



** includes tidal,wave, geothermal, solar, wind, biomass (peat, wood, straw, cow dung etc)

Energy conversion 1Mtoe = 4.48 x 10^{16} Joules

Figure 1.2 Global Energy use by energy source

Per capita energy use for several countries is given in Figure 1.3

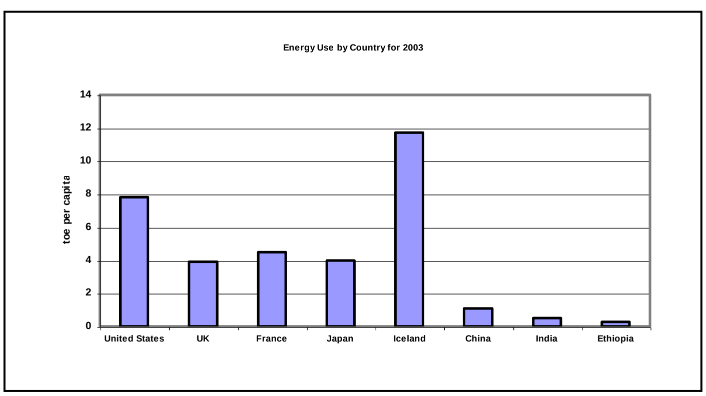


Figure 1.3 Per capita energy use (full list given in http://earthtrends.wri.org/text/energy)

In Figure 1.1 all the numbers are in Watts which represents the rate of energy flow (Joules per second.). In Figure 1.2 the present day world energy consumption is approximately 11,000 Mtoe or 5×10^{20} Joules. Since there are 3×10^{7} seconds in a year the fossil fuel is being used at a rate of about 1.7×10^{13} watts.

Ignoring global warming for the moment, it is seen in Figure 1.1 that 35% of solar radiation is reflected before it reaches the earth and the remaining 65% is re-radiated as infra-red (IR) energy so that there is a balance of input and output. The temperature of the earth has settled down to about 293 °K (or 20 °C) which is **most important** for life on earth. Water, on which we are very dependant, is liquid at this temperature and therefore can be used as a ***life giving fluid*** in the plant and animal kingdoms.

In Figure 1.1, *renewable energy* can be obtained from the "Direct Conversion" pathway with Solar Heating Panels or Photovoltaic cells. Water wheels or hydroelectric generation are sources by which energy is extracted from the energy stored in the hydro-cycle ("Storage in water vapor") and wind, wave and biomass are the other routes for tapping into the sun's energy. On the right hand side of Figure. 1.1 there are Tidal and Geothermal energy sources. Although the number of Watts in each of these cases looks very encouraging, all these sources are sparsely distributed. For instance, the mid-ocean tidal range is less than a metre and is only amplified to useable amounts in estuaries. Similarly Geothermal energy is concentrated in volcanic areas which limits this as a source of energy.

The small **text box** at the bottom of Figure. 1.1 has the title **Fossil Fuels** and this is the human intrusion into nature's balanced energy equilibrium. This box yields a value of 1.7×10^{13} Watts which is the rate of energy use at present and it is **a small fraction of the solar radiation** arriving on the earth's surface. One may well think that such a small amount of fossil fuel energy would have little effect on the world's energy balance but the carbon dioxide gas produced from burning fossil fuels builds up in the atmosphere and absorbs the outgoing infra-red (IR) radiation and re-directs it to earth. As one is aware, one only needs a small proportion of this radiation to be added back to earth and then the earth's temperature will rise. Then, if this causes the ice caps to melt, the initial reflected light (35 % in the diagram) will be less as land or water in the polar regions will not reflect light as well as snow or ice. We are then in, what some say, is a vicious circle where a disturbance in the energy equilibrium causes a further disturbance and the final equilibrium temperature would be unpredictable.

From historical records there is good evidence that temperature cycles are part and parcel of the earth's passage through time. But it would appear that, in the past two or three decades, temperature changes, shown in Figure 1.4., are outside those expected from natural effects and that the burning of fossil fuels is the primary cause of this change.

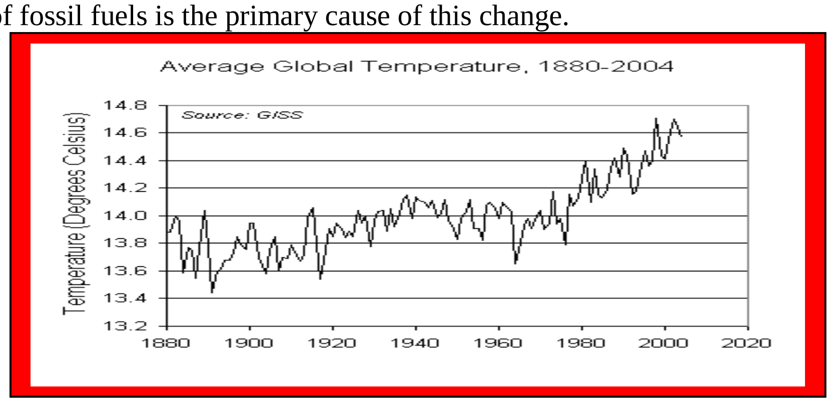


Figure 1.4 Graph of average Global Temperature over the last few decades

One only needs to look at the rise in atmospheric carbon dioxide levels to see that there is an obvious correlation between temperature rise and carbon dioxide.

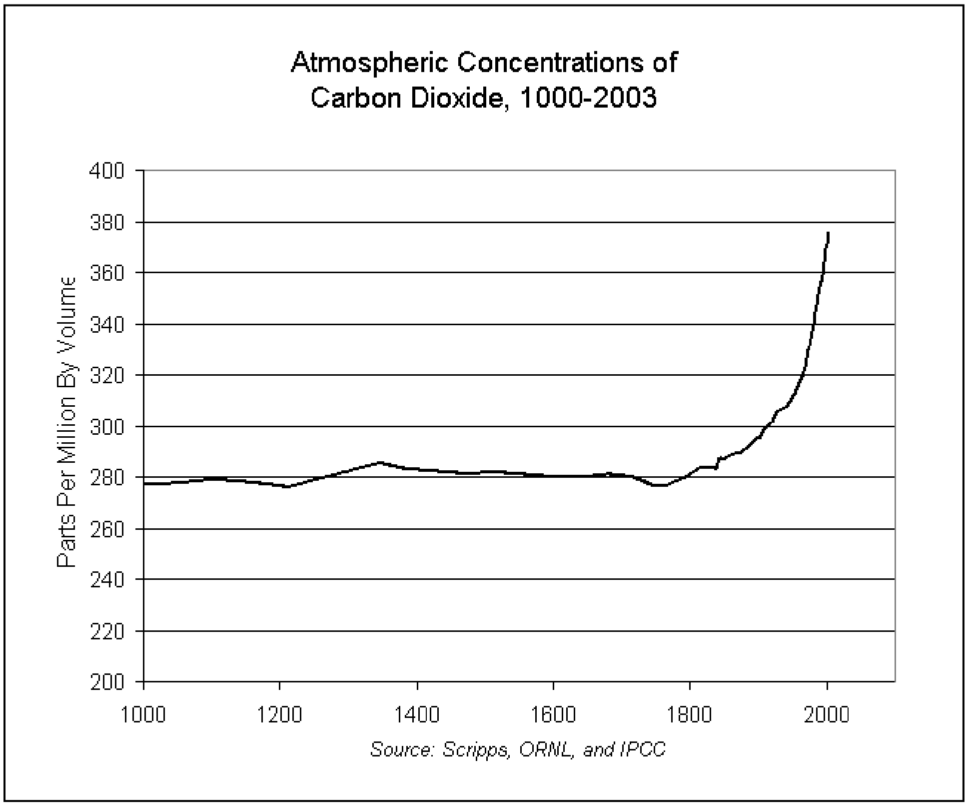


Figure 1.5 Atmospheric carbon dioxide levels

For centuries the atmospheric CO_2 levels have been in the region of 280 parts per million by volume and only in recent years has there been a dramatic increase to a value of 380 ppm as depicted in Figure 1.5.

At all cost the use of fossil fuels must be curtailed so that we become more reliant on renewable or sustainable energy sources.

Many nations have given serious consideration to this problem. In 1997, in Kyoto, Japan, there was an international conference on Climate Change which alerted the world to global warming. Specific targets for cutting emissions of greenhouse gases were agreed by many of the participants and this has become known as the Kyoto Protocol. The European Union agreed to a 5.2% reduction in these gases within the decade 2000 to 2010. Other members have embarked on a variety of changes of energy usage and one of the targets that the UK government has set itself does appear very challenging indeed but eminently laudable. Electrical generation from renewable sources is to be increased such that 10% of electricity supplied in 2010 will have come from renewable sources and that, by 2020, this will be increased to 20%. Yet some countries, notably USA, China and India, have not subscribed to this protocol and it can only be concluded that CO_2 levels will continue to rise ever more rapidly. What dire consequences await the human race!!

Yvo de Boer, executive secretary of the United Nations Convention on Climate change gave an optimistic discussion on the TV programme "Hardtalk" about future carbon emissions (20 June 07). It is difficult to share this optimism as many countries feel that, historically, the West is to blame for the current situation. They also point out that the per capita emissions are still very high in the developed world as Figure 1.6 shows.

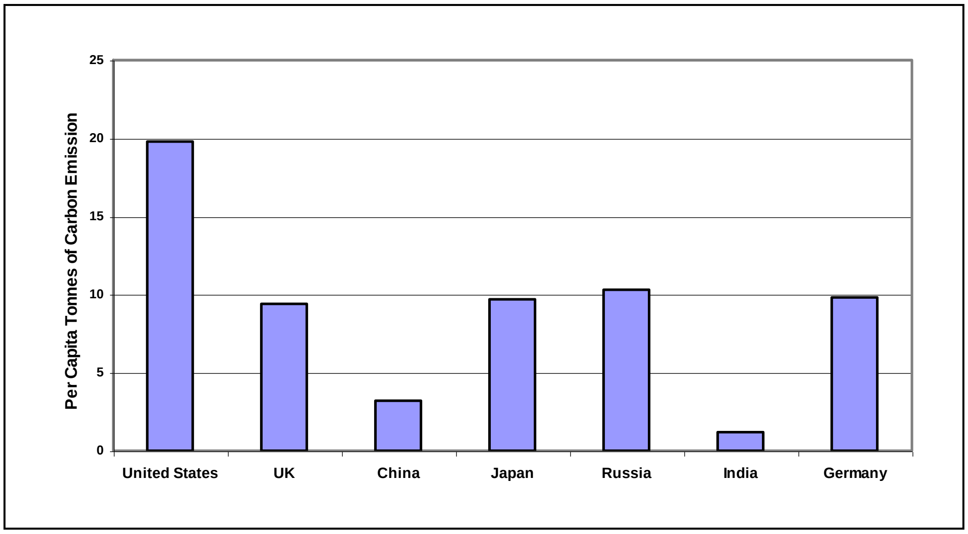


Figure 1.6 Carbon emissions per person for selected countries (source ONC statistics 2006)

Concern over the use of fossil fuels comes, also, from a very obvious fact that any non-renewable source of energy is bound to be used up after a period of time.

The first person to bring this to the attention of the public was Marion King Hubbert who suggested that the production of coal and oil would reach a peak in production and then decline as the resources ran out. Much is now written about the Hubbert Peak since it is a matter of conjecture as to when the production maximum will occur – this year, next year, some year in the distant future – are all possibilities. Tied in with such forecasts are questions of security of supply and the pricing of fossil fuels. Technologies of energy supply which now appear very uneconomic will possibly be our mainstay for future supplies.
Fig 1.7 is an illustration of Hubbert's early warning which was included in the Science journal.

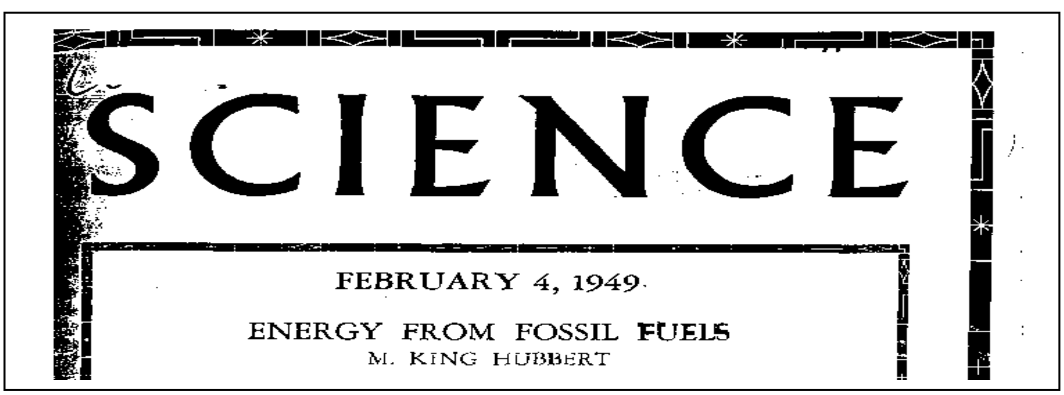


Figure 1.7 Energy from fossil fuels by Marion King Hubbert

Hubbert followed this earlier article with a more substantial document in 1956 and since that time the use of fossil fuels has been a discussion point amongst scientist.
Unfortunately, economists and politicians are not well versed in science and are generally more interested in completely different aspects of life; to name but two - short term fluctuations of Stock Markets or the general health of the Health Service. Even when the Energy Crisis of the early 1970's presented itself there was very little change to the consumption of energy. Figure. 1.2 does show slight fluctuations in the total energy used in the 1970 – 80 period but this was mainly due to mild recession over that decade.
Thus, globally, one is hard pressed to find any reason for a significant fall in fossil fuel usage and the most probable action is some form of carbon trading so that Western countries can stay within their Kyoto limits up till 2012. (Less industrialised nations may not be using their full carbon quota and will therefore be able to sell it to a nation who is likely to overshoot their quota.) Most analysts agree that the energy rise as shown in Figure. 1.2 is, at best, an optimistic outlook and that a massive 20,000 Mtoe will the total energy used in the year 2040.
Further reading:
Hubbert's Peak – book review

BOOK REVIEWS

Daniel V. Schroeder, *Editor*
Department of Physics, Weber State University, Ogden, Utah 84408; dschroeder@weber.edu

Hubbert's Peak: The Impending World Oil Shortage. Kenneth S. Deffeyes. 208 pp. Princeton U.P., Princeton, NJ, 2001. Price: $35.00 (cloth) ISBN 0-691-09086-6; $16.95 (paper) ISBN 0-691-11625-3. (Mark P. Silverman, Reviewer.)

I have read numerous books that were informative, a smaller number that in addition were entertaining, and very few that had the potential, as well, to be life-changing. *Hubbert's Peak* is in this last category. That we live on a finite planet with a finite fossil energy supply may seem upon reflection an obvious, if not banal, observation. However, to judge from the relatively low level of public concern over the rate at which nonrenewable resources are being exhausted, it is fairly clear that most people do not think about, or do not understand, the sweeping implications of this simple fact. M. King Hubbert first brought the "bad news" to the oil industry in 1956. And Kenneth Deffeyes, through the medium of this comparatively short, highly readable, and carefully argued book, is bringing it to the general public.

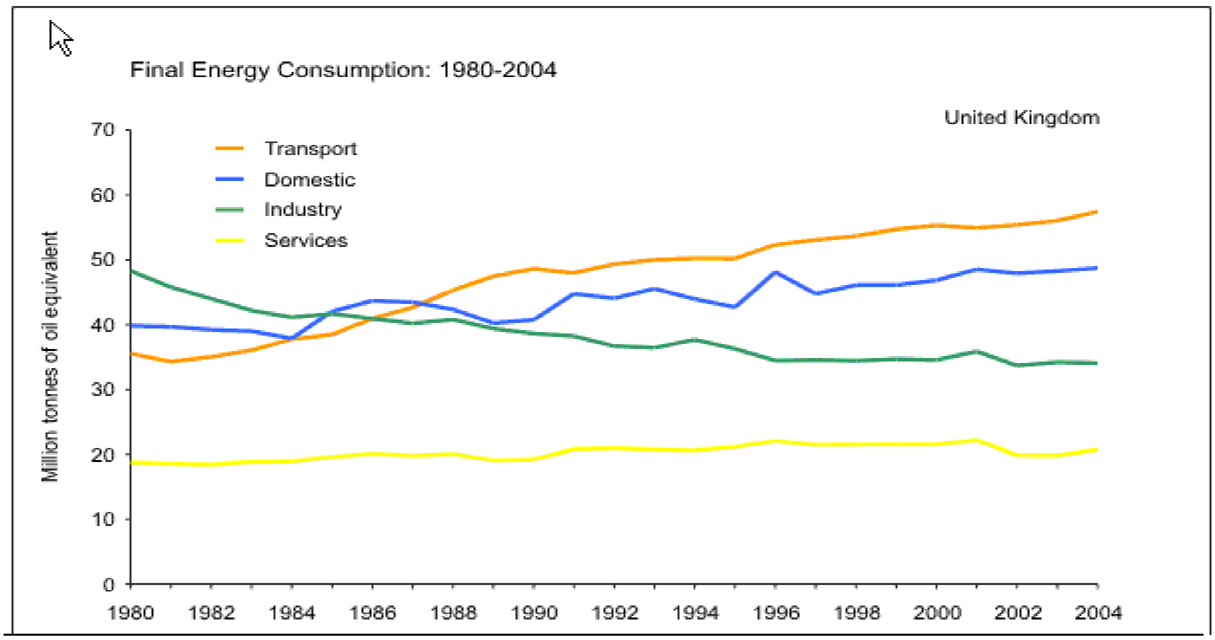
A geophysicist by training, Marion King Hubbert made numerous scientific contributions of a fundamental nature. For example, he demonstrated that fluids can become trapped under circumstances previously not thought possible, and that even the hardest rocks on the earth's surface become soft like mud or clay when subjected to enormous pressure. However, what projected Hubbert to fame—or notoriety—was his assessment of the finite availability of the world's petroleum supply. In 1956 at a meeting of the American Petroleum Institute, Hubbert—against the strenuous objection of his employer, the Shell Oil Company—predicted that U.S. oil production would reach a peak in the early 1970s. This is bad news indeed if one is counting on an endless supply of accessible and cheap petroleum to sustain an unrealistic vision of unremitting economic growth. Although there have been numerous cries of wolf in the past, Hubbert's prediction was close to the mark: the peak year for U.S. oil production turned out to be 1970. Since that time, the United States has hard-core science." Certainly the oil companies must have thought so for, according to Deffeyes, "...neither Shell nor the rest of the oil industry was ready to listen to Hubbert's prediction. It was as if a physician had diagnosed virulent, metastasized cancer; denial was one of the responses." Indeed, as recently as 2000, Deffeyes informs us, the president of the American Association of Petroleum Geologists published yet another denial of the validity of Hubbert's results.

Looked at superficially, there is a certain deceptive simplicity to Hubbert's model that has invited numerous criticisms. Fitting the annual rate of oil production then available to him with a symmetric curve, Hubbert deduced the projected peak year of production and, from the area under the curve, the total consumable supply. There are many ways, however, to thwart Hubbert's argument, and the author, who has a whimsical sense of humor, proposed the following as his favorite: "...[I]nvite the Saudis to join us as our 51st state."—this was undoubtedly written before 9/11—"Now you count the Saudi oil as U.S. oil; Hubbert is toast." Deffeyes, of course, clearly recognizes the fallacy of such reasoning, since "...first you must draw a line around the problem and then discuss what goes on inside the line. Fudging the line, either geographically or categorically, only makes a mess out of the discussion." True, but there is more to this fallacy than fudging boundary lines. Hubbert's model embodies truths much deeper than curve fitting.

I have been teaching energy and society courses for many years, usually to students whose facility with mathematics is rather limited, and have unfailingly evoked a certain degree of consternation whenever I worked out on the blackboard the simple consequences of geometric growth—as, for example, the time required to exhaust a nonrenewable resource whose annual consumption increases at a fixed rate. I usually worked with geometric, rather than exponential, growth because the former involves no more than algebra, whereas the latter entails the calculus, but the results were close either way and invariably surprised those (the majority of the class) who were not exposed before to the idea of compounding.

II National Issues – the Energy White Paper 2007

The Energy White paper, *meeting the energy challenge*, was published in 23 May 07 (www.dti.gov.uk/energy/whitepaper/page39534.html). This document formulates the government's strategy for keeping a secure supply of energy at reasonable costs and, at the same time, being sensitive to environmental matters.
The general reactions to the document have been very mixed – "342 pages of waffle including much talk of targets and aspirations but nothing for the energy industry to get its teeth into" from the Independent to "a realistic framework for future energy developments" in the Times. Perhaps one could suggest that it is a much more positive document than the Energy White paper of 2003 and, as it follows in the wake of the Stern report on climate change, it addresses problems of greenhouse gases in some details. Instead of just "Conservation" and "Increases in Renewable Energy" in the 2003 paper, many more topics are discussed, including North Sea resource depletion (page 109), CO_2 capture and storage (section 5.4) Tidal (page 144) and Nuclear Energy (section 5.5).
So how fast are we consuming our energy and is it going to run out? Statistics from Defra www.defra.gov.uk/environment show that the amounts of energy used over the past years have been quite steady with energy increases in the transport and domestic sectors being off-set by reduction of consumption in the industrial sector. Clearly, on a world market energy will not run out but North Sea oil and gas ***will become depleted*** over the next decade or so.



Year	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Annual Total (Mtoe)	**142.4**	**147.3**	**158.3**	**161.5**	**156.9**	**158.4**	**160.4**	**161.3**

Figure 2.1 UK Final Energy Consumption 1980 - 2004

An energy flow chart for 2004 is included in the Digest of UK Energy Statistics 2006 (www.dti.gov.uk/energy) and this shows that the primary demand in 2005 was close to 250 million tonnes of oil equivalent (Mtoe) resulting in a final consumption of 161.0 Mtoe. (Conversion losses 22% other uses and distribution losses 14%)

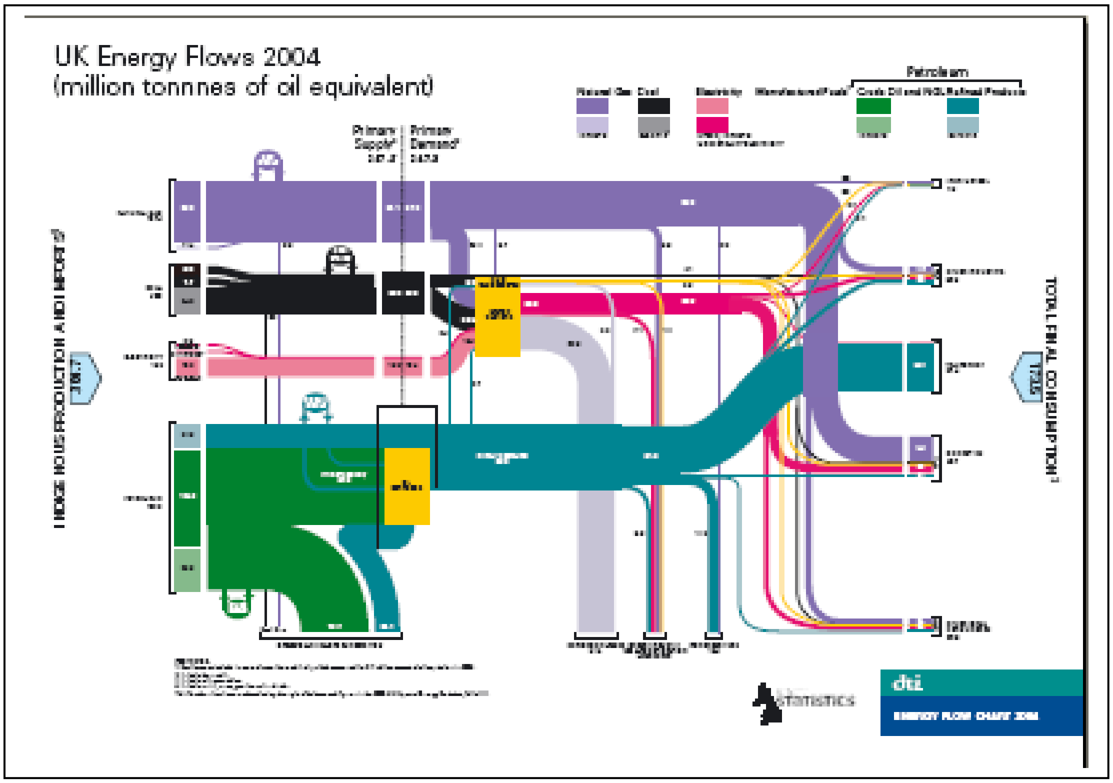


Figure 2.2 UK Energy Flow for 2004

Both Figures 2.1. and 2.2 cannot hide the fact that, presently, 90% of UK's energy needs are met by oil, gas and coal and the White paper suggests (page 106) that little will have changed by 2020 with the energy mix envisaged as:- coal –14%, oil – 39%, gas – 40%, nuclear –3% and renewable sources –4%. It is difficult to believe that fossil fuels will have 93% of the UK energy market more than a decade hence when we know that these fuels are the primary cause of global warming. It is doubly difficult to believe that the paper places such reliance on oil and gas when it states that 80% of gas and 75% of oil will have to be imported as reserves in the North Sea become depleted (illustrated in Figure 4.2, page 109 of the White Paper). One would have to question the security of these imported commodities as we have already experienced a turning off of the gas taps in 2005.

A second problem for the UK is raised in paragraph 5.2.11, page 128. I quote "over the next two decades , the UK will need substantial investment in new generation capacity around 20 – 25 GW of new power stations will be needed by 2020 and a further 10 GW

by 2030". At present, UK has around 76 GW of electricity generation capacity to meet an annual consumption of 350 TWh. The renewable part of this is
3 GW or 4% of the total generating capacity. Projected figures of 10% generation from renewable sources by the year 2010 and 20% by 2020 appear to be totally unrealistic but other sources like tidal stream and wave power may augment the energy supplied by wind turbines.

The positive aspects of the White paper are that there will be continued pressure to conserve energy in the domestic and transportation sectors (Chapters 4 and Chapters 7). As illustrated in the diagram, these are the two areas where large amounts of energy are presently being used and, therefore, any cuts will be beneficial to the total energy demand.

Increased funding for renewable energy sources (page 216) is also welcomed as this is likely to boost industrial/ academic collaborative work. Concerns on Skills Shortage have already been expressed by the Leitch Review and the White paper sets out plans to redress any such shortages and suggests that overseas recruitment may bolster experience levels whilst the skills of the UK workforce are further developed (page 230, para 6.43) It praises our current school system (page 233) and doesn't see the need for any changes. Undoubtedly, physicists will have eminently suitable qualifications for tackling energy related problems in the future.
The two highly controversial topics Tidal power in the Severn Estuary (page 144) and Nuclear Power (page 180) are still at a consultative stage.

There is good coverage of carbon emissions in the White Paper, Chapter 5, and the United Kingdom has often taken a lead in suggesting a framework for cuts in these emissions. However, the global scene is not encouraging and China and India will both work towards economic growth as a primary objective. Even if both countries doubled their per capita emissions they could claim to give less carbon pollution, in per capita terms then North America or Europe.

In summary, the White paper 2007 gives many more strategies for tackling future energy problems than those presented in 2003. The document does show that the government is prepared to offer rather more "carrot than stick" in its energy development program but that the highly controversial decisions regarding Tidal and Nuclear power and CO_2 elimination by carbon-capture and storage have yet to be taken. The possible "generation gap" may be circumvented by a continuation of the dash for gas as it has been reported recently that RWE npower is to build a gas fired power station at Staythorpe, Notts.

III Issues regarding a domestic home

To take a giant leap now from global and national issues to those of the home one sees that this is where energy saving must begin. The vast majority of people use electricity and gas in their homes and it is easy to see if each person used a little less then the accumulated saving would be colossal.

The Energy Saving Trust shows many ways of how to save energy.

Figure 3.1 How to run your home

Ten Top Tips are included below.

Top ten tips

They say you have to speculate to accumulate and, by following these simple top ten tips below, you're guaranteed a great return on your investment, both financially and environmentally.

The energy saving measures below could help you shave up to £300 off your annual energy bill and enable you to reduce your carbon dioxide emissions by two tonnes. Here's how you do it.

1. Brush up on energy saving
Eliminate draughts and wasted heat by installing a cheap, easy-to-fix brush or PVC seal on your exterior doors. Letterboxes and keyholes should be covered too.

2. Draught dodgers
Draughts also get in through gaps in floorboards and skirting boards, which also allow heat to escape in the winter months. Filling them with newspaper, beading or sealant will help you stop throwing heat (and your money!) away. Click here to find out more information on draught proofing.

3. A bright idea & buy an energy saving light bulb
Trade your ordinary light bulbs for energy saving ones. Costing from just £3.50, energy saving light bulbs last 12 times longer and for each bulb you fit, you could save up to £9 on your annual electricity bill or £100 over the bulb's lifetime. Click here for more information on energy saving lighting.

4. Treat your tank & give it a jacket
An insulating jacket for a hot water tank only costs a few pounds and pays for itself within months. Fit one that's at least 75mm (3") thick and you could save around £20 a year. If every UK household fitted a jacket on their tank tomorrow, we'd save over £95 million of energy every year! Click here for more infromation on hot water tank insulation.

5. Lofty ambitions
Insulating your loft is one of the simplest ways to save energy and you can even install it yourself. Insulate you loft today and in a year you could between £180 and £220. Click here to find out more about loft insulation.

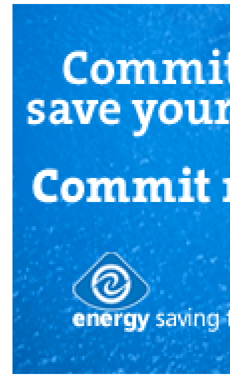
6. Look for cavities
Around 33% of the heat lost in your home is through the walls, so insulating them can be the most cost-effective way to save energy in the home - you could save £130 to £160 on your annual heating bills! Cavity wall insulation will also keep you cool in the summer and warm in winter. It's straightforward, inexpensive and hassle-free. If we all had our cavity walls filled tomorrow, together we'd save over £962 million of energy every year. Click here to find our more about cavity wall insulation.

7. Boilers - it may not be broke but it might still need fixing!
If your boiler is over 15 years old it's probably time to replace it. By law, new boilers must now be of the high-efficiency condensing type. They can help you save up to a third on your heating bills and even more if you upgrade to modern controls. Click here for more information on boilers.

8. Look for the logo
When replacing appliances, look for ones displaying the energy saving recommended logo. Energy saving appliances use less energy and could save you up to £45 a year. Click to find energy saving recommended products.

9. See double...and cut heat loss by 50%
Double-glazing cuts heat loss through windows by 50% and could cut your heating bill by £80 to £100. Click here to find out more about glazing.

10. Take our online home energy check
Still not sure which are your home's weak spots? Why not complete our online home energy check? If you'd prefer to speak to someone you can call a local energy efficiency advisor on 0800 512 012.



Got a question?

Find the answer with our frequently asked questions and answer

Figure 3.2 Ten Top Tips

It is always as well to remember that only a few decades ago life used to be very different to present day living and a more sustainable lifestyle was being lived by many people. The following article by John Humphrys illustrates this quite graphically

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Wasting away

John Humphrys goes back to his boyhood to find an answer to global warming - but it's not for the faint-hearted

See as separate file .....

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Have a look at our use of electricity

Well it is obvious that we cannot turn the clock back to the time of John's parents but action of some kind must be taken and a "start" would be to do an energy audit for the home.

	Average power (watts)		Daily usage (hours)		Total (watt-hours)	
	Example	Your house	Example	Your house	Example	Your house
Kitchen						
Lights	20 watt CFL*		3.0		60	
Fridge	190		8		1520	
Microwave	1200		0.25		300	
Toaster	600		0.2		120	
Food processor	500		0.1		50	
Other						
Laundry						
Lights	15 watt CFL		1		15	
Washing machine	600		1		600	
Iron	1200		0.4		480	
Sewing machine	60		0.1		6	
Other						
Loungeroom						
Lights	2 x 20 watt CFL		4		160	
TV	120		2		240	
Video	110		1		110	
Stereo	60		2		120	
Vacuum cleaner	1000		0.2		200	
Other						
Bedroom 1						
Lights	15 watt CFL		1		15	
Other						
Bedroom 2						
Lights	15 watt CFL		0.5		8	
Other						
Workshop						
Power tools	300		0.5		150	
Pump	100		1		100	
Other						
Total Energy Consumption					4254	

* Compact fluorescent lamp

Next we could read the electricity and gas meters. This is direct evidence of the amount of energy being consumed in the home. A typical gas meter is shown in Figure 3.4:

Figure 3.4 Gas meter

The numbers are very clear to read and they represent the gas consumption in cubic metres. Data is given below to show gas consumption figures.

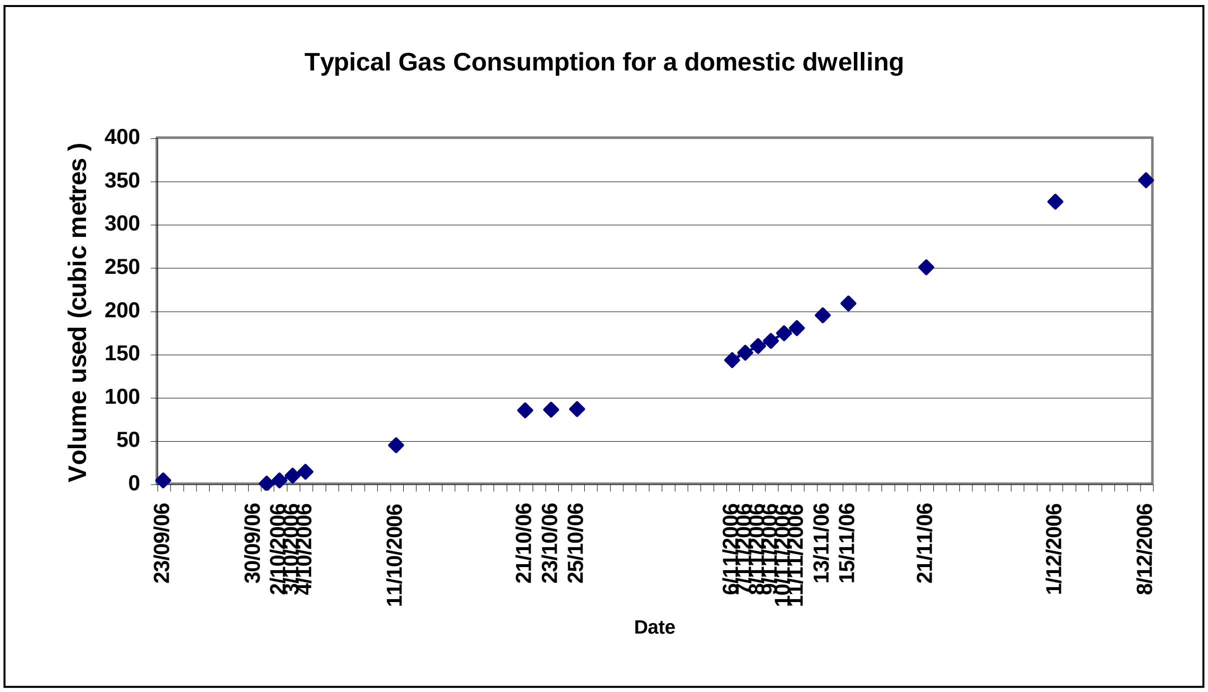


Figure 3.5 Gas meter readings

For the timer set to "hot water twice per day", date 30/09/06, the average consumption was 4 cubic metre per day.
With additional "heating twice per day", date 06/11/06, the consumption doubled to 8 cubic metres.
Note - gas supply turned off over period starting 21/10/06.

The electricity meter gives Units (ie kWatt-hr) and the graphical data was much simpler than gas consumption - in summer it was approximately 6.5 kWatt-hr per day whereas in winter the consumption increased slightly to 7.5 kWatt-hr per day.

Conservation of energy will inevitably alter life style but one change that is worth doing immediately is to change ordinary light bulbs to compact fluorescent (CF). The following graph compares the "current footprint" of an ordinary 60 watt bulb with a CF giving the same light output.

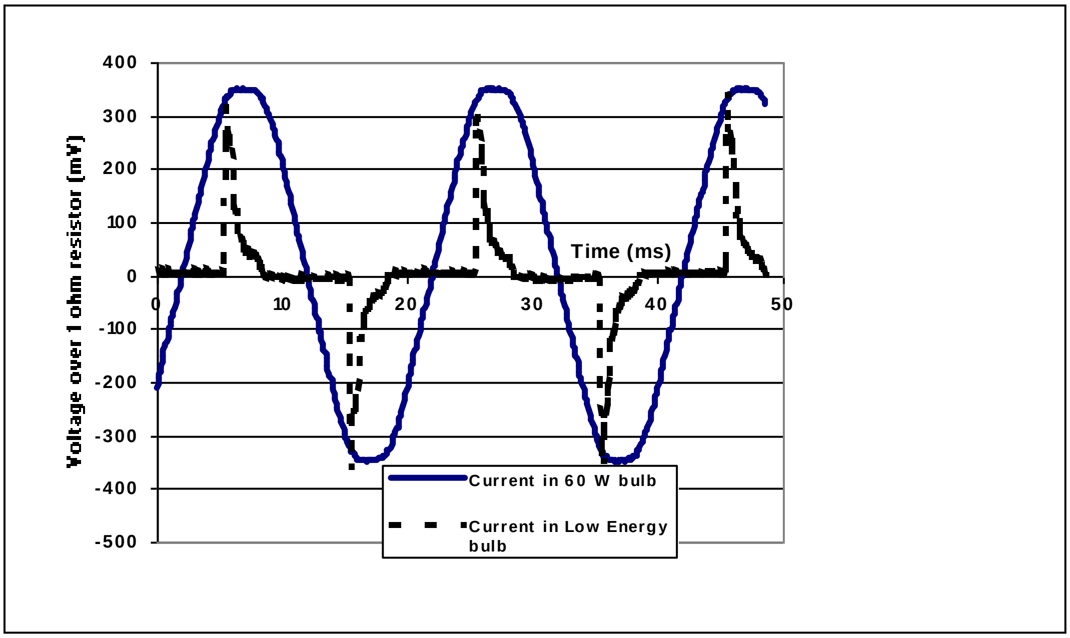
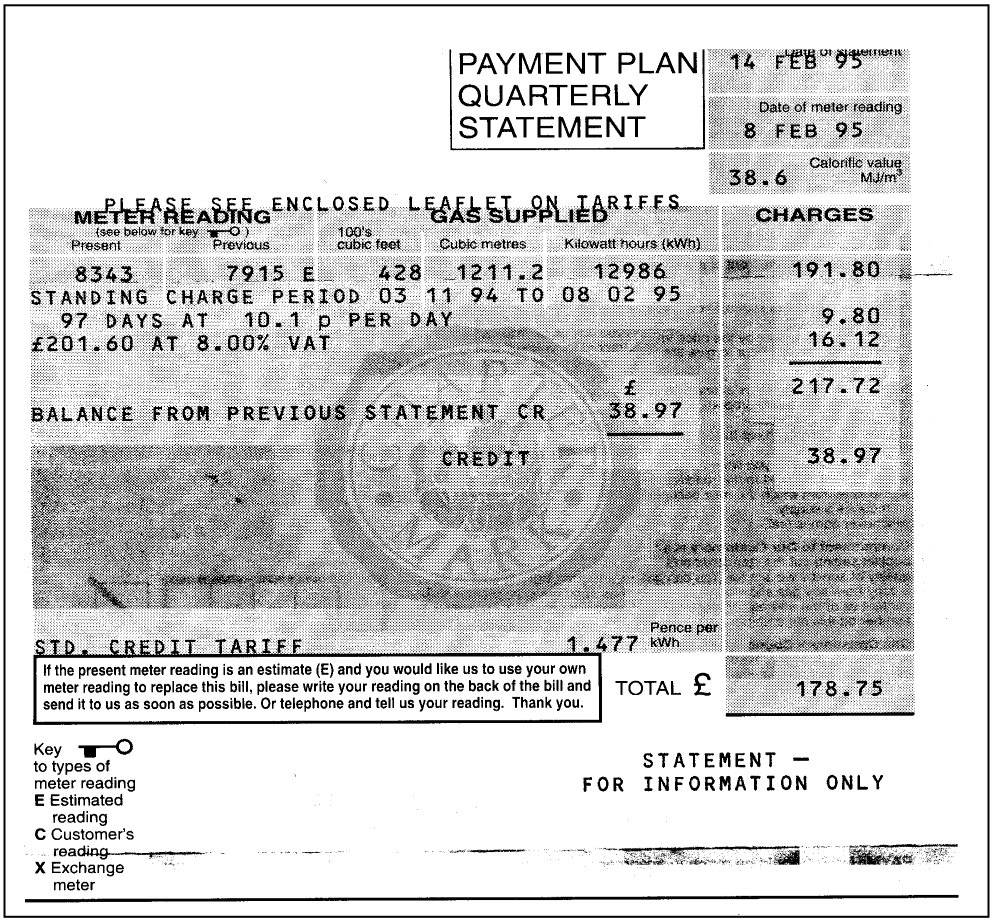


Figure 3.6 Current "footprint" of light bulbs – note the dashed curve shows that the Bulb is off for considerable parts of the ac-cycle and therefore no power (Volts x Current = Watts) is consumed.

As one can see the 60 watt bulb is taking current (the "y-scale" is also mAmps as 1 mV over 1 Ohm is 1 mAmp) all the time whereas the CF bulb is only switched on for little bursts. A newer type of light source the White Light LED could also be used as this converts electrical power directly into light.
The current "footprint" of any household item can be measured and it goes without saying that leaving items of electrical equipment on "stand-by" does consume significant amounts of electricity. So, the rule is SWITCH OFF WHEN NOT IN USE.
Space heating will always be the greatest component of the Gas bill. An example of how gas charges are made is given in Figure 3.7 from winter 1994/95.



PAYMENT PLAN
QUARTERLY
STATEMENT

Date of statement 14 FEB 95

Date of meter reading 8 FEB 95

38.6 Calorific value MJ/m³

PLEASE SEE ENCLOSED LEAFLET ON TARIFFS

METER READING (see below for key) Present	Previous	GAS SUPPLIED 100's cubic feet	Cubic metres	Kilowatt hours (kWh)	CHARGES
8343	7915 E	428	1211.2	12986	191.80

STANDING CHARGE PERIOD 03 11 94 TO 08 02 95
97 DAYS AT 10.1 p PER DAY — 9.80
£201.60 AT 8.00% VAT — 16.12

217.72

BALANCE FROM PREVIOUS STATEMENT CR £ 38.97

CREDIT — 38.97

STD. CREDIT TARIFF 1.477 Pence per kWh

If the present meter reading is an estimate (E) and you would like us to use your own meter reading to replace this bill, please write your reading on the back of the bill and send it to us as soon as possible. Or telephone and tell us your reading. Thank you.

TOTAL £ 178.75

Key to types of meter reading
E Estimated reading
C Customer's reading
X Exchange meter

STATEMENT — FOR INFORMATION ONLY

Figure 3.7 Gas bill from the winter of 1994/95

The consumption of gas over the 97 day period was 1211.2 cubic metres so that the daily consumption was 12.5 cubic metres per day. This is in excess of that given in Figure 3.5 and therefore already we are beginning to see gas conservation measures are being taken by the household. The energy content of gas is listed as 38.6 million Joules per cubic meter and this does vary as gas is taken from different fields in the North Sea. To convert gas supply in m^3 to kWatt-hr one uses a factor of 10.7 or about TEN. It is thus obvious that the energy used from the gas supply is about 10 times that of the electricity supply,

namely, 90 kWatt-hr for gas 7.5 kWatt-hr for electricity

More than a decade ago the cost of units electricity: gas was 10 : 1 and so the final bills were approximately the same. However, recent tariffs quoted to the writer were:-

4.339 pence per kWatt-hr for gas and 8.38 pence per kWatt-hr for electricity.

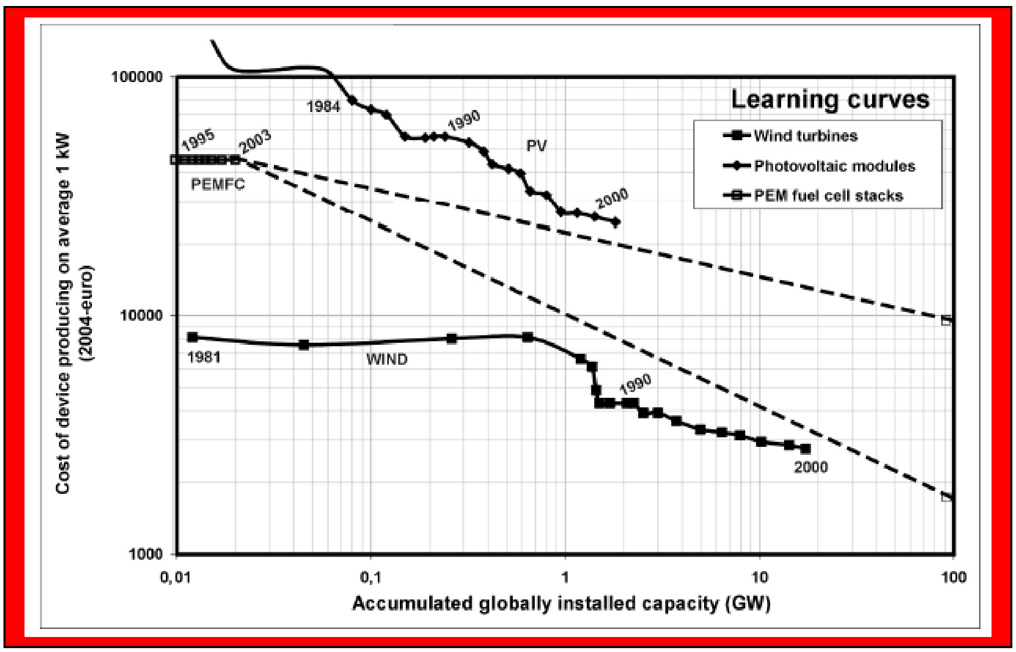
Ten years ago the price of gas was 1.477 per unit.

One can only suggest that good insulation, loft and walls and double glazed windows to minimise heat losses and turn the thermostat down- in fact TEN TOP TIPS. Wearing an additional sweater will conserve body heat and a brisk walk at some part of the day will help to self-generate that inner heat.

IV Self-help issues

Suburbia is not the ideal location from which to branch out into self-sufficiency (energy or otherwise) in a big way. In TV's "The Good Life" Tom and Barbara carried audiences to fits of laughter but we have every right to be sceptical along with Jerry and Margo.

The initial attraction of Sun and Wind are that they are free to all and that installations costing from a few hundreds to a few thousand pounds can be sited on or near one's house.
In general terms the technologies of wind energy can be realised for lower costs than solar energy as the following diagram shows:



(PEMFC stands for proton exchange membrane fuel cell and is one of the newer emerging technologies.)

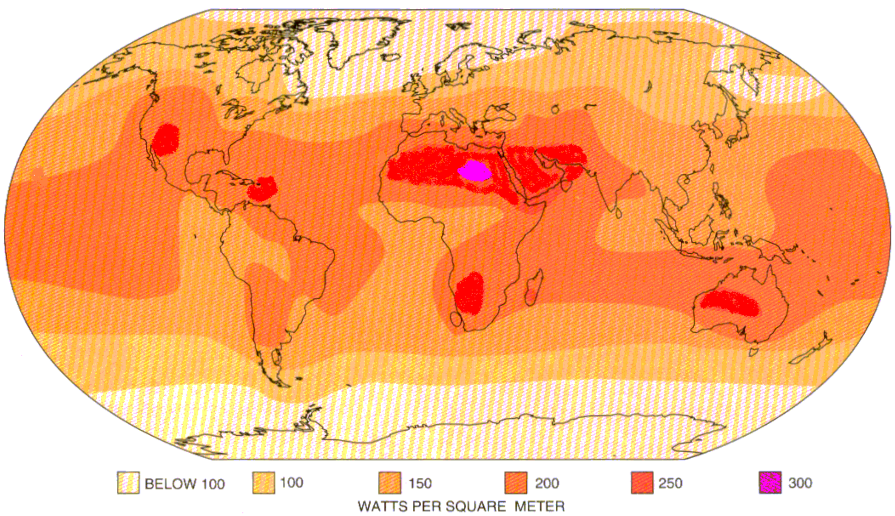
Figure 4.1 Costs of wind and solar technologies

As one can see, costs have reduced as more and more units are installed but wind power is lower in cost compared to Photovoltaics. The author has no experience with solar heating but this is most likely to be the cheapest option of all in getting energy into the home. With grants it is possible that a hot water installation will be in the £1000 to £2000 cost bracket.

Some details of solar radiation are given below:

SOLAR ENERGY

There is a plentiful supply of solar radiation reaching the earth but it is concentrated in the equatorial regions. This is shown below:-



AVERAGE AMOUNT OF SUNLIGHT (in watts per square meter) falling on a horizontal area of the earth's surface is shown for a 24-hour period. The abundance of sunshine makes it an obvious source of energy. To be a practical source, however, the energy derived from sunlight must be converted to a form that can be transported and stored.

Figure 4.2 Solar map of the world

This diagram shows the solar radiation averaged over the seasons and, in addition, averaged over a 24 hour period. North Africa has the maximum solar insolation with a value of 300 watts per square meter but, for the UK, a value of 100 watts per square meter is given.

A trial on solar radiation was conducted since four ex-Ferranti Photovoltaic modules were available for experimentation. The results of this trial is given below:

PHOTOVOLTAIC CELLS are they a viable energy source for the North West regions of UK?

Ever since the human race started to use FIRE there has been an awareness of an obvious fact that *fuels, once burnt, cannot be re-used*. And so it is with the Hydro Carbons (coal, oil and gas) of today- when they're gone they are gone for good.
It has only been in the last few decades, however, that another awareness has emerged and this has to do with the environment :-
burning fuels at the present rate is creating a severe imbalance in nature, namely, global warming. This will have dire consequences if not checked immediately as sea levels could rise by a meter or more as the polar ice caps melt. Many millions of people will have to move from low lying fertile regions of the world if sea levels rise in such a dramatic manner and one hesitates to think of the consequences.
In 1997, in Kyoto, Japan, there was an international conference on Climate Change which alerted the world to global warming. Specific targets for cutting emissions of greenhouse gases were agreed by many of the participants and this has become known as the Kyoto Protocol. The European Union agreed to a 5.2% reduction in these gases within the decade 2000 to 2010. Other members have embarked on a variety of changes of energy usage and one of the targets that the UK government has set itself does appear very challenging indeed but eminently laudable. Electrical generation from renewable sources is to be increased such that 10% of electricity supplied in 2010 will have come from renewable sources and that, by 2020, this will be increased to 20% .One takes one's pick from a bewildering array of possible renewable sources of energy:-
Solar, Wind, Tidal, Wave, Hydro-electric, Bio-fuels in their many forms, Geothermal (though this is strictly not renewable) and, perhaps, other sources of energy not yet conceived.
To focus on just one of these, electricity from the sun, this is how the government is prepared to help UK citizens take the plunge!
As from May 2002, anyone with a house will be eligible to apply for up to half the cost of installing solar panels on their roof. "But at what cost?" you will naturally ask. The investment for a most basic system is typically £14,000 which would mean that the householder's share is £7,000. Spending such sums of money is not to be undertaken lightly and one would need to be assured that the basic system would deliver meaningful amounts of energy, particularly in winter when the sun is not a frequent visitor to our skies.
(For details of the grant, see the web site of the Energy Saving Trust – http://www.est.org.uk)
(Anyone wishing to know more about how sunlight interacts with a silicon cell to produce energy – the so called photoelectric effect - should consult the web site of the Australian Centre for Renewable Energy, http://acre.murdoch.ade.au.)

In order to find out if this source of energy could be viable in the future for the UK, a small solar array has been placed in a south facing location (the author's home) in the Greater Manchester area to monitor the electrical output over an extended period of time. A summary of the results is given below for the twelve months of 2003.

Technical Details

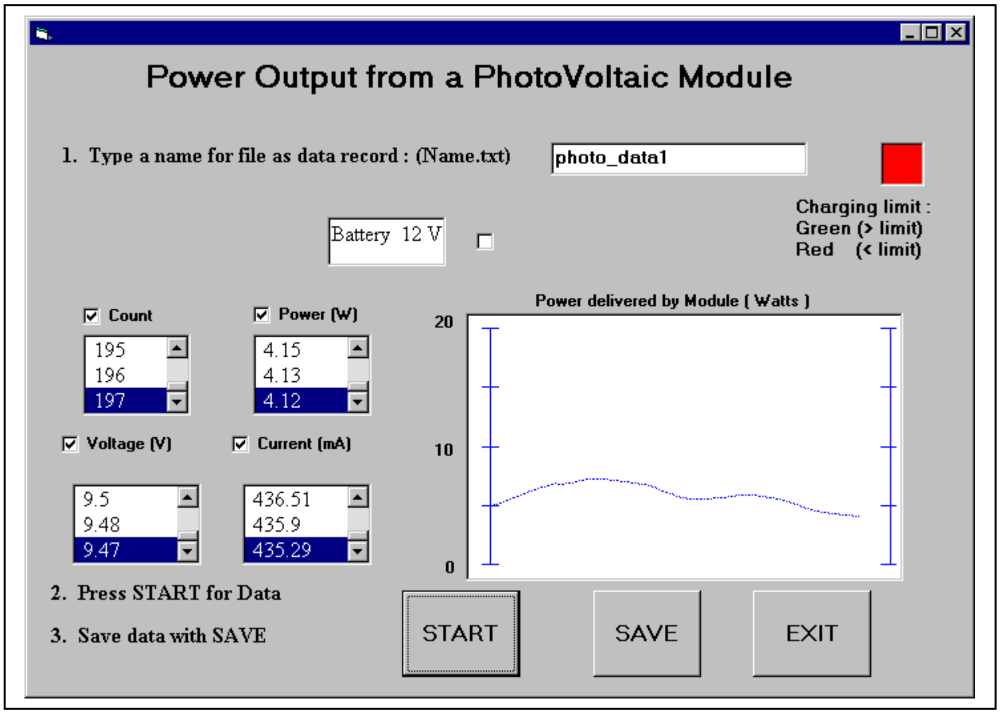
Each module, made up of 36 cells connected in series, was manufactured by the Ferranti Company, Chadderton and are specified to give an output of 15 Volts, 1 Amp in bright sunlight. The four modules, used in this investigation, failed to meet the full manufacturer's specification and only ONE module (lower right in the illustration) gave an acceptable output of 12 Watts, maximum, in full sunlight.

Monitoring of output from solar cells

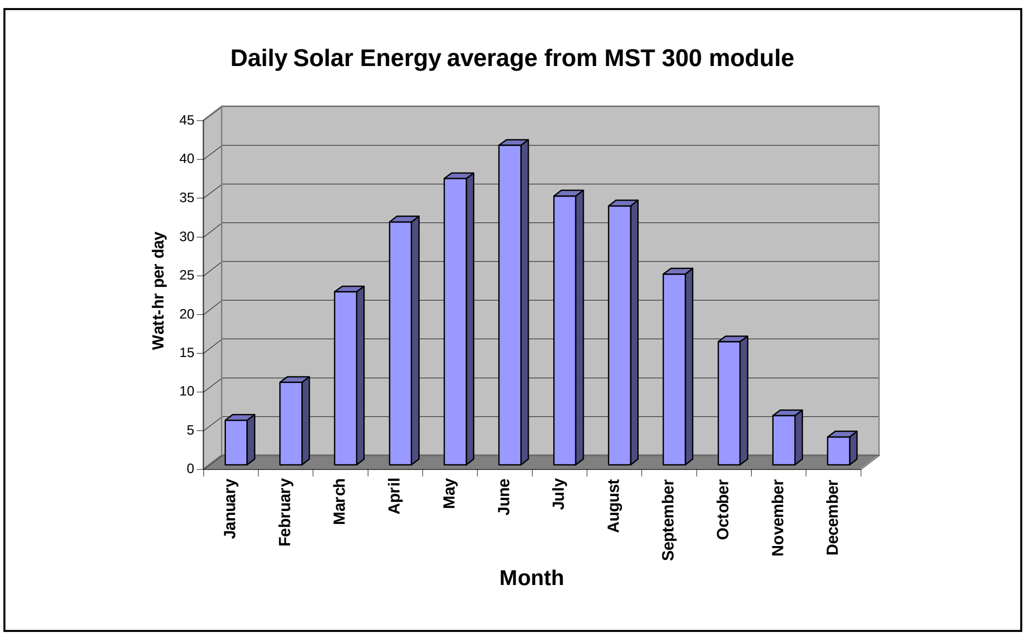
The output from each module was fed into resistive loads comprising of a 20 Ohm resistor in series with a 1 Ohm resistor. The voltage generated over the 1 Ohm resistor was used to monitor current supplied from the module and the direct voltage output from the module was stepped down to a value suitable for interfacing to a computer. All eight voltages were data logged using a Pico ADC 11 interface unit thus requiring eight inputs of the eleven provided by the interface unit. A further input was used to log the outside temperature, purely as a matter of interest.

A VISUAL BASIC program allowed current and voltages to be logged and stored for all modules and, for the lower right module, current, voltage and power were displayed on screen at 5 second intervals during a 12 hour period. A graphical display of this power output was displayed for the last 200 points to indicate variation in power level. As the modules were designed to charge batteries, an indication of voltages in excess of the battery voltage is given on the screen.

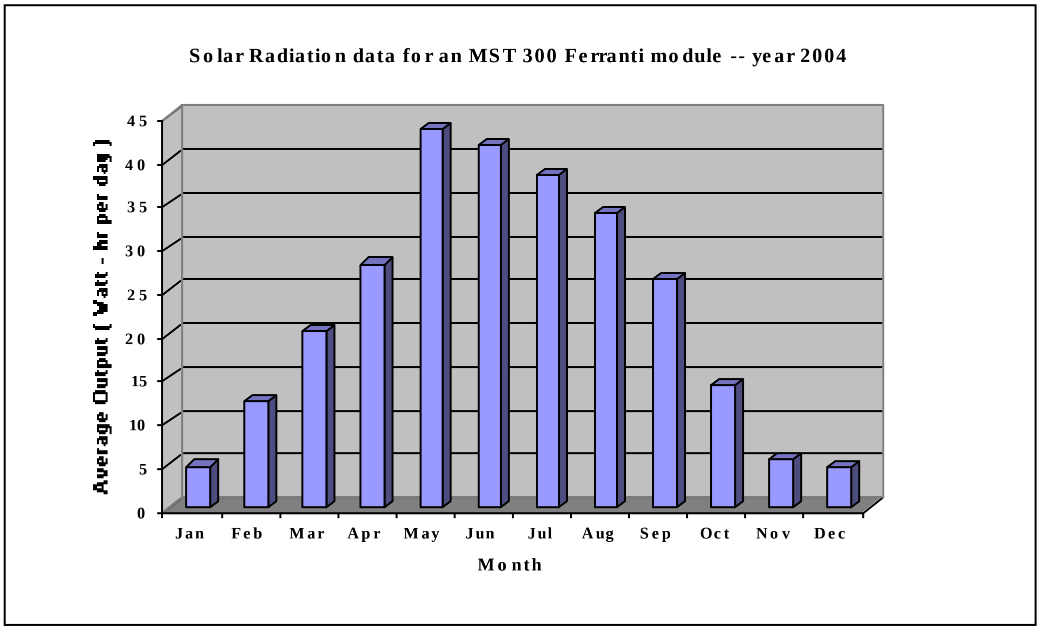
The format of the screen display is given below:-

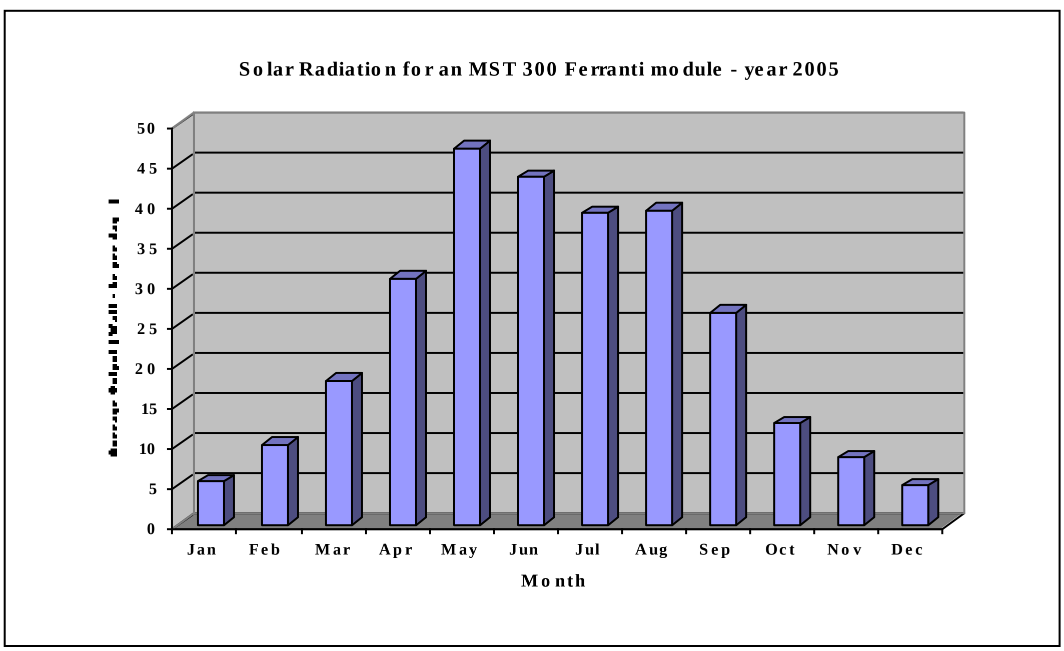


By integration over a 12 hour period the cumulative energy from the module was determined as a daily average. This was then used to produce monthly averages which are displayed below. **Below is data for the year2003.**



Solar data for two subsequent years, namely, 2004 and 2005 are given below and look very similar to that given for 2003. Very small Watt-hr values are achieved in the winter months.





Conclusions

From an environmental point of view, it must be stressed that energy conservation is always top of the list when discussing energy matters. If, however, one is concerned about a secure supply of electricity from the "mains", then photovoltaic electricity would have to be augmented by wind energy and the exploitation of off-shore wind farms, in combination with photovoltaic arrays, would appear to be the most attractive method of producing "green" energy in the future .

F.Thompson@manchester.ac.uk

Post Script

The "mains" electrical energy consumed by a family in a four bed-room detached dwelling was also monitored over the years 2003, 2004 and 2005 and the average daily use amounted to 6.5 kWatt-hours. Since the maximum daily output from the module was very close to 65 Watt-hours on 16th June 2003, it would require an array of 100 modules to provide the required electrical energy on that particular day. A much larger array would be required to meet demands in the winter months.

WIND ENERGY

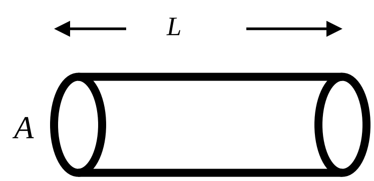
Wind energy has now almost become a *domestic issue* as the multi-store B&Q are supplying small wind turbines. A few details of wind power will now be given:

Any moving mass has kinetic energy, K.E., given by the equation :

$$K.E. = \tfrac{1}{2}mv^2$$

For a cylindar of air

Length L and area A



we have mass = A L x density
If L is numerically equal to v then all air passes A in one second

So $$\textbf{Power} = \tfrac{1}{2}\, \textbf{A x density x } v^3$$

We can see that the power is proportional to the CUBE of the windspeed thus, high windspeeds are very important for this type of energy source.

This form of renewable energy offers better prospects for the UK then Solar Energy, as the following map shows.

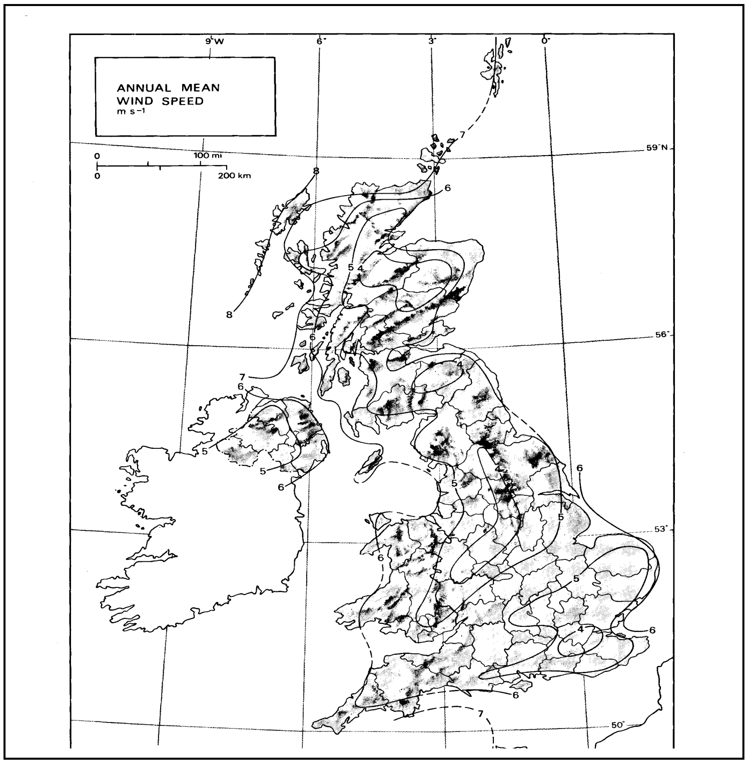


Figure 4.3 Wind speed contours for the United Kingdom

In addition, wind energy is available when it is most needed – in the winter months as the following diagram shows.

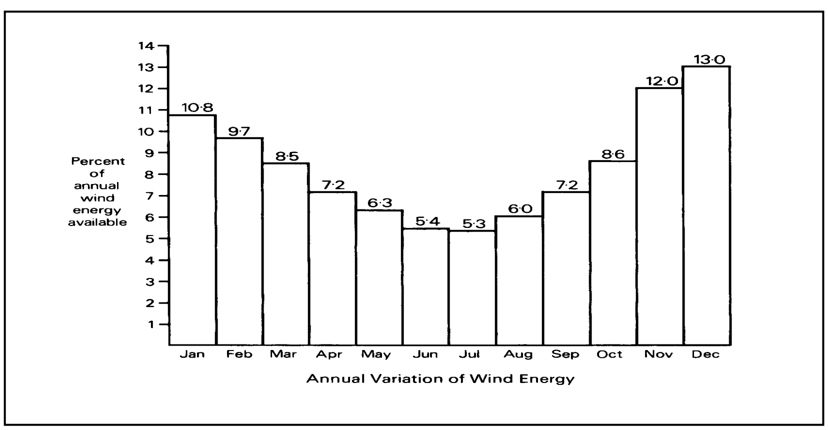


Figure 4.4 Wind energy data

It can therefore be concluded that wind energy offers better prospects than solar energy for the UK.
One is aware that many people find windmills to be unsightly. Therefore, consideration of building wind farms off-shore should always be made so that the scenic beauty of a landscape is not destroyed.Indeed, the recent Government approval for the Thames Estuary Wind farm should be welcomed. It will have 341 turbines rising from the sea between Margate in Kent and Clacton, Essex. As the wind speed contours show (Fig 3.3), this area is a very favorable site having an average annual wind speed of 6 metres per second.

No experiments have been carried out by the author with wind generators but the advantage of wind power is, clearly, that high outputs occur in the winter months when most energy is needed.

V Conclusions

Most town dwellers have limited means of circumventing any energy hardships that are likely to arise in the future.
Many elderly people do already sink into energy poverty in the winter months and the Government's winter fuel payments are pitifully low.
Security of supply is another aspect of energy which is bound to become more critical as time passes. From basking in North Sea oil and gas for many years, these commodities are now having to be purchased on the open market.
On an optimistic note we must remember that people have lived without central heating in the past. Therefore a policy of ensuring comfort heat in one room may become more normal that trying the heat up the whole dwelling. Walking, cycling and using public transport will all help to reduce fuel bills for cars and very probably will have added health benefits.

Attached to the present work are two articles

Pedal power which was published in Undercurrents in 1976 February-March, Number 14, page 21.

Denmark's energy policy by Amos.
Separate file given a Denmark's Sustainable future

Web sites --- large number listed for any search, three sites given below:-
www.itdg.org explanation of windpower systems
www.baxi.co.uk manufacture heat pumps and solar heating units.
www.sundog-energy.co.uk install wind or solar units for domestic and industrial needs.

More information is given for fossil fuel use.
The so-called Sankey diagram (energy flow as in Figure 2.2) for UK is given for 1979 and predicted for 2025. Diagram are taken for the text “An Atlas of Renewable Energy Julian Mustoe, Wiley 1984. It is very doubtful that the diagram for 2025 will be achievable at that future date.

POWER TO THE PEDAL

Exercising machines, you may well think, are a symptom of the sedentary and unhealthy way of life pursued by modern urban man — part of the problem of 20th Century civilisation, rather than part of the solution. But given that a great many of us are fated to live and work for the foreseeable future in situations where the opportunities for exercise are very limited, an exercise machine, as Frank Thompson argues, has its advantages — especially if you can use it as a standby electrical generator as well. Alternative technology purists who scorn the mains as a backup supply could find such a machine useful when the cottage lights are dimming and the windmill stands maddeningly becalmed.

"The only exercise I get is when I take the studs out of one shirt and put them in another."
Bartlett's Unfamiliar Quotations.

FOR MANY PEOPLE in urban areas the above quotation contains more than a germ of truth. Exercise should be an essential part of man's activities and, although this may be carried out in recreational or other centres, an exercise machine in the home has a number of advantages:

- exercise may be taken at the most convenient time
- after the initial cost there are no recurrent costs such as admittance charges to recreational centres
- exercise is independent of the weather.

Many commercial exercisers are available, but all have one feature in common: *they dissipate energy.* Because energy conservation is important at the present time

COSTS

	£
Secondhand alternator type 17 ACR	14.24
Chains	1.26
Small sprocket (7 tooth) from lawn mower	0.50
Cycle parts (estimated)	1.00
Constructional parts (estimated)	1.00
TOTAL	£18.00

and is likely to be even more important in the future, we thought that an exercise machine which would store energy would be extremely useful. The electrical battery probably provides the most convenient method of storing energy, so it was decided to construct a machine to convert muscle power into electrical energy. The battery could then supply power to a low voltage lamp for day to day use or, if necessary, it could be connected to an invertor which would provide an emergency 'mains' electrical supply. The only design criteria adopted in the project were that the machine should (i) operate satisfactorily (ii) be cheap and (iii) be easy to assemble. Therefore we felt it was necessary to use mass-produced components (preferably secondhand) from cars, bicycles and household equipment and assemble them in a fairly simple manner.

We realise that similar projects will have been carried out previously but no data was readily available.

Design

Human energy conversion

An assessment of the rate of energy conversion within the human body is an extremely complex problem. However, from Fig.1 it can be estimated that a power output of 100 watts can be sustained by an average person for about one hour.

A secondhand bicycle was used in the construction of the machine primarily for economic reasons, but also because it is generally accepted that a person in a normal cycling position can develop a high output of mechanical power.

Electrical generation

Car alternators and d-c generators have power ratings of between 100 and 500 watts and are, therefore, compatible with the power output from the human body. A Lucas alternator, type 17 ACR, was used in the machine and a typical output characteristic is shown in Fig.2.

The advantage of using an alternator instead of a d-c generator is that the latter requires higher rotational speeds for a given output current. In addition, most alternators have an integrated control box and rectifier unit so that external connections are simply made to two terminals.

Power transmission

From the previous section it can be seen that alternator speeds of between 1000 and 2000 r.p.m. are required and, since a person can pedal at a rate of approximately 100 r.p.m., a gear ratio of greater than 10:1 is necessary. To produce this gear ratio from bicycle parts a two stage gear system is needed.

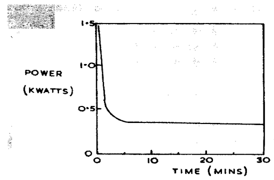


Fig.1. Mechanical Power Developed by Athletes[1].

Description

The electrical circuit and details of the two stage gear system are shown in Fig.3.

For test purposes, an ammeter was included in the circuit, but only the pilot light is necessary to ensure that the machine is operating satisfactorily.

A resistor, which forms part of the circuit,

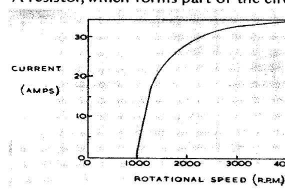


Fig.2. Output Characteristics of the 17 ACR-type Alternator[2].

limits the charging current to about 8 Amperes otherwise too much pedal power is required. It is simply a length of heater wire with a resistance value of 0.05 ohms. The intermediate gear consists of two sprockets welded on to a bicycle front wheel bearing. A third sprocket is fitted to the alternator shaft on a special bush which was fabricated in a lathe and the fourth sprocket is the chainwheel of the bicycle. The gear ratio is approximately 19:1. The complete machine is shown in the photograph.

Operation is extremely simple. The battery is connected as shown in Fig.3(a) and this causes the pilot light to glow. The pedals are then turned at a sufficiently high rate to cause the pilot light to be extinguished and the battery is then being charged.

Conclusions

The exercise machine was constructed simply and cheaply and has been operating satisfactorily for some months. If

Continued on page **26**

Undercurrents

Continued from page 21

a complete bicycle is available the alternator unit can be substituted for the rear wheel. Alternatively, a simple support could be made so that the rear wheel of the bicycle transmits power to a roller which then turns the alternator shaft.

The cost of commercial cycle exercisers is approximately £50, compared with which the cost of the exercise machine described in this article is relatively small; as a bonus, the expended human energy is stored as electrical energy in a battery.

References

1. Adapted from Fig.20 p301 *Exercise Physiology*. Ed. Harold B Falls, Academic Press 1968.
2. *Workshop Instruction Manual* (Nov 1968) Joseph Lucas Ltd.

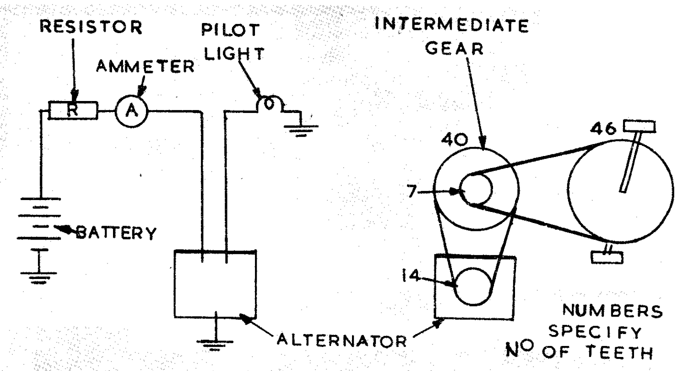


Fig.3. Details of the Exercise Machine:(a) electrical circuit; (b) gear system.

Will global warming trigger a new ice age?

If you can remember back to the bitter winters of the late 1970s and early 80s you might also recall that there was much discussion in scientific circles at the time about whether or not the freezing winter conditions were a portent of a new ice age.

Over the past couple of decades such warnings have been drowned out by the great global warming debate and by consideration of how society might cope in future with a sweltering planet rather than an icebound one. Seemingly, the fact that we are still within an interglacial period, during which the ice has largely retreated to its polar fastnesses, has been forgotten - and replaced with the commonly-held view that one good thing you can say about global warming is that it will at least stave off the return of the glaciers.Is this really true, or could the rapidly accelerating warming that we are experiencing actually hasten the onset of a new ice age? A growing body of evidence suggests that, at least for the UK and western Europe, there is a serious risk of this happening - and soon.

The problem lies with the ocean current known as the Gulf Stream, which bathes the UK and north-west Europe in warm water carried northwards from the Caribbean. It is the Gulf Stream, and associated currents, that allow strawberries to thrive along the Norwegian coast, while at comparable latitudes in Greenland glaciers wind their way right down to sea level. The same currents permit palms to flourish in Cornwall and the Hebrides, whereas across the ocean in Labrador, even temperate vegetation struggles to survive. Without the Gulf Stream, temperatures in the UK and north-west Europe would be five degrees centigrade or so cooler, with bitter winters at least as fierce as those of the so-called Little Ice Age in the 17th to 19th centuries.

The Gulf Stream is part of a more complex system of currents known by a number of different names, of which the rather cumbersome North Atlantic Meridional Overturning Circulation (Namoc) is probably the most apt. This incorporates not only the Gulf Stream but also the cold return currents that convey water southwards again. As it approaches the Arctic, the Gulf Stream loses heat and part of it heads back to warmer climes along the coast of

Greenland and eastern Canada in the form of the cold, iceberg-laden current responsible for the loss of the Titanic. Much, however, overturns - cooling and sinking beneath the Nordic seas between Norway and Greenland, before heading south again deep below the surface.

In the past, the slowing of the Gulf Stream has been intimately linked with dramatic regional cooling. Just 10,000 years ago, during a climatic cold snap known as the Younger Dryas, the current was severely weakened, causing northern European temperatures to fall by as much as 10 degrees. Ten thousand years before that, at the height of the last ice age, when most of the UK was reduced to a frozen wasteland, the Gulf Stream had just two-thirds of the strength it has now.

What's worrying is that for some years now, global climate models have been predicting a future weakening of the Gulf Stream as a consequence of global warming. Such models visualise the disruption of the Namoc, including the Gulf Stream, as a result of large-scale melting of Arctic ice and the consequent pouring of huge volumes of fresh water into the North Atlantic, in a century or two. New data suggest, however, that we may not have to wait centuries, and in fact the whole process may be happening already.

So that the warm, saline surface waters of the Gulf Stream can continue to push northwards, there must be a comparable, deep return current of cold, dense water from the Nordic seas. Disturbingly, this return current seems to have been slowing since the middle of the last century. Bogi Hansen at the Faroese fisheries laboratory, and colleagues in Scotland and Norway, have been monitoring the deep outflow of cold water from the Nordic seas as it passes over the submarine Greenland-Scotland ridge that straddles the North Atlantic at this point. Their results show that the outflow has fallen by 20% since 1950, which suggests a comparable reduced inflow from the Gulf Stream.

Although there is as yet no direct substantiation of this, and his colleagues point to reports of the cooling and freshening of the Norwegian Sea and to temperatures that are already falling in parts of the region as possible evidence of contemporary Gulf Stream weakening.

It also seems that it is not only the intensity of the outflow of cold water that is changing. Bob Dickson of the Centre for Environment, Fisheries, and Aquaculture Science at Lowestoft, and colleagues, have reported a sustained and widespread freshening of returning deep waters south of the Greenland-Scotland ridge, which appears to have been going on for the past three or four decades.

Already the freshening is extending along the North American eastern seaboard towards the equator, in the so-called Deep Western Boundary current.

One of the scariest aspects of the current dramatic changes occurring in the system of North Atlantic currents is that the deep, southward-flowing limb of the Namoc can be thought of as representing the headwaters of the worldwide system of ocean currents known as the Global Thermo-haline Circulation. The possibility exists, therefore, that a disruption of the Atlantic currents might have implications far beyond a colder UK and north-west Europe, perhaps bringing dramatic climatic changes to the entire planet.

Further information www.whoi.edu

Fossil Fuels

Coal, lignite, natural gas, and crude oil are the fossilized remains of ancient plants and animals, and it is on account of their method of formation that these fuels have been given their generic title. Other parts of the energy flows begin in the kinetic energy of flowing river water, the heat of the inner parts of the Earth, and in the forces existing within the nuclei of uranium and plutonium atoms. The last two energy resources, geothermal and nuclear, are ultimately finite although they are so large that they could hardly be exhausted by any conceivable level of human activity. Forgetting for a moment the obstacle in the way of gaining access to them, nuclear and geothermal energies can best be described as quasi-renewable resources. River energy is, however, a truly renewable resource for a river's water only flows because it is continuously replenished by meteorological processes. Collectively the energy sources at the left of the Sankey diagrams are described as primary energies in recognition of the fact the flows of energy in the world's economies originates with them.

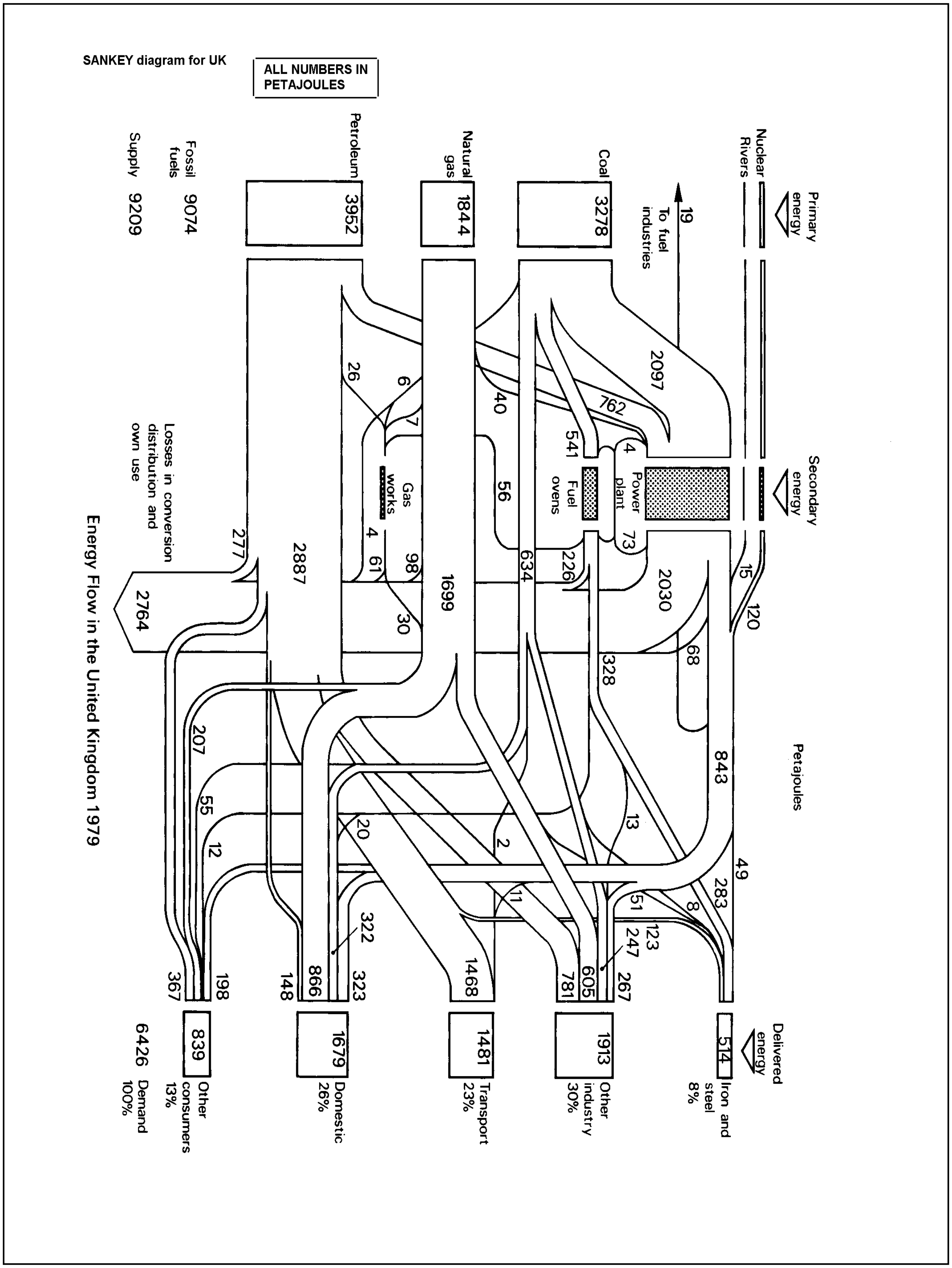
Rather than being delivered directly to consumers, primary energy can, as a matter of convenience and utility, be transformed into other secondary forms of energy that do not occur in nature. Coal can be gasified and distributed as a fuel of medium thermal value. Coke, the nearly pure carbon residue of coal after roasting, is used as a fuel for smelting iron ore and to a small extent as a boiler fuel. But by far the most useful, extravagant, and controversial secondary fuel is electricity. Electricity is from the standpoint of the consumer an almost ideal fuel. It is versatile, clean in use, easily controlled, and can be utilized in simple appliances. Sometimes it seems to be a commodity possessed of almost magical properties. Electricity is everywhere much in demand, and its production forms a large part of the economic activity of all industrialized nations. But electricity generation is a process beset by difficulties and fraught with many disadvantages.

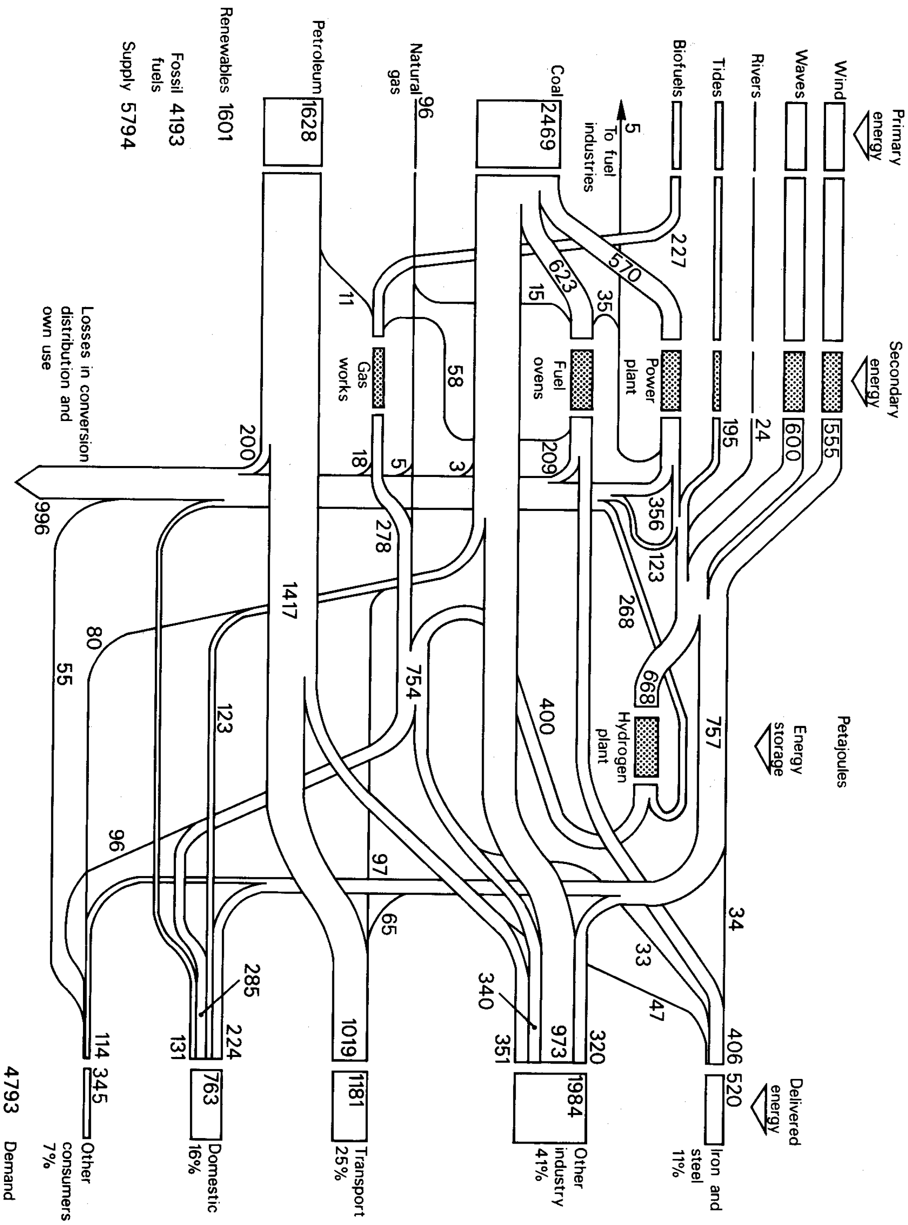
The most conspicuous drawback, evident from Figure overleaf, is the immense waste of energy resulting from electricity generation. The flow of waste heat out of the economy, represented by the flows toward the bottom of the diagrams, is largely made up of electricity power station losses. This is not caused by shortcomings in design and engineering, but follows from the fact that thermodynamic considerations limit the thermal efficiency of electricity generation to a maximum of approximately 38 per cent. The most modern power stations approach this figure closely, although average plant efficiencies in 1979 were 27 per cent in the United Kingdom and 19 per cent in North America. Consequently more than two-thirds of the thermal content of fuel burnt in power stations is rejected to the environment and lost. Further losses in distribution bring the overall efficiency of the British system down to 25 per cent of the primary fuel invested. Thus it is that in the United Kingdom the heat wasted by Central Electricity Generating Board power stations is 64 per cent of the thermal value of all the coal delivered to market by the National Coal Board. An even more fantastic situation prevails in North America where 78 per cent of the value of all coal produced is lost in the course of electricity production and distribution. These enormous losses will continue as long as waste heat from power stations is simply dissipated to the environment. Measures to reduce this waste by putting the rejected heat to use are discussed in the concluding chapter of this atlas.

In use electricity gives an impression of cleanliness. It is invisible and weightless, produces no fumes and leaves no ash or residue. But from a national standpoint it can be seen that electricity, while removing dirt from the surroundings of the consumer, concentrates pollution at the site of production. Many tons of carbon dioxide, sulphur, nitrogen compounds, and dust are discharged into the atmosphere by a power station's boilers in the course of a year's operation. As well as polluting the neighbourhood of the power station the effects of burning coal in large quantities are felt hundreds of miles from the place of origin. Degradation of rivers and forests as far away as, for example, Norway and Sweden can in part be attributed to the output of British chimneys.

Energy Flow in UK for1979 and projected diagram for 2025

Note 1Mtoe = 44.8 PetaJoules





Energy Flow in the United Kingdom in 2025

Multiples used in Science		symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a