PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Introduction

William Hawthorne

Phil. Trans. R. Soc. Lond. A 1980 **295**, 345-347
doi: 10.1098/rsta.1980.0131

Phil. Trans. R. Soc. Lond. A 295, 345–347 (1980)
Printed in Great Britain

Introduction

By Sir William Hawthorne, F.R.S.
University Engineering Laboratory, Cambridge

I should like to welcome participants on behalf of the Royal Society to the meeting for discussion on solar energy. To set the scene I can misapply the Shakespearian quotation, 'A universal largess like the sun His liberal eye doth give to everyone' and go on to add 'Thawing the cold fear'† of energy shortages to come. The Sun's liberal eye has provided energy for the Earth's surface at the rate of over 50×10^{12} t of coal equivalent per year, that is some 5000 times greater than our present rate of energy consumption. Apart from providing direct warmth, indirect solar energy has been used for many years. The biomass, in the form of wood, was the earliest source of energy. Even now, wood supplies a surprisingly large amount of primary fuel. In North America, for instance, the amount of wood used is about equivalent to the total consumption of primary fuel by Denmark, or some 7% of U.K. consumption. Later tallow, vegetable oils and the fossil fuels, coal, peat, lignite and some mineral oils came into use for heating, cooking, lighting, pottery making and primitive smelting and manufacturing.

Solar heat and fuels were not used for power or work. The first sources of power for man, other than his own and his animals' muscular power, were provided indirectly by solar energy via the atmosphere, through wind acting on sails and windmills and through rain acting on waterwheels.

About 250 years ago the picture was radically and forever changed by the invention of the steam engine. This was done principally and most effectively by Newcomen, who devised a machine that used fuel for producing work.

Between 1712, when Newcomen's first engines were built, and 1780, when Watt greatly improved their performance by adding the separate condenser, windmills and waterwheels were producing 6–11 kW (8–15 h.p.). Steam engines of up to 18.6 kW (25 h.p.) were being used for pumping water from mines and some for producing rotary motion. The advantages of the steam engine were extolled because it provided a source of continuous and uninterrupted power available when needed and was not dependent on the whims of the wind or the flow of water.

Since then, the World has become increasingly dependent on the use of fossil fuels, not only for producing power for electricity, traction and other uses, but also for heat, manufacturing and the chemical and metallurgical industries. Today the World consumes primary fuel at the rate of over 2 kW per person and in countries such as the U.S.A. and Canada the rate is over 10 kW per person. Some $\frac{2}{3}$ of the primary fuel is in the form of oil and natural gas. Furthermore, the rate of increase of world energy consumption has been running at about 5% per annum, and the rate of increase of petroleum consumption has been even greater.

It is only comparatively recently that we have become aware of the implications of these large rates and rates of increase of consumption. They are related to the economic growth that most countries now consider, in various degrees, to be a politically desirable objective, if the natural aspirations of their increasing populations are to be satisfied.

† *Henry V* IV.i.43.

Many studies of World energy supply and demand and of projected national and regional energy requirements suggest that there will be an increasing strain on conventional petroleum and natural gas supplies to the point where substitution for these fuels on a large scale will become necessary towards the end of the century, if not before.

The largest increase in petroleum prices in 1973 focused attention on these problems, but if the general conclusions of the studies are accepted an increase in oil prices appears to have been inevitable, however ineptly done, and further increases may be expected.

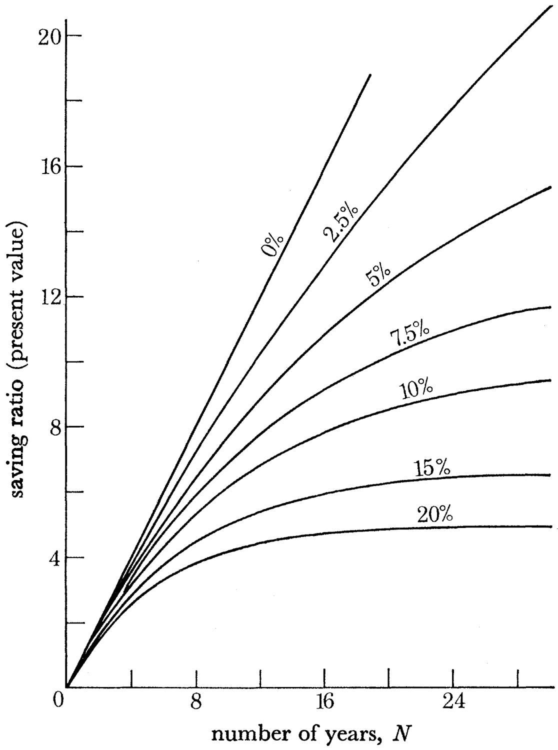

Figure 1. Present value of total fuel saved as a function of time in years.

In this atmosphere, Governments have re-examined their energy policies, not only with the object of relieving the immediate strain on their balance of payments due to the high oil prices, but also to anticipate the likely need to substitute for oil and gas in the future. One element in such policies is energy conservation and the extended use of renewable resources of energy.

This meeting is to discuss one aspect of these policies, namely the potential of solar energy as a future energy resource. It has been said that 'The separation of emotional and logical inputs to the assessment of the prospects for effective use of the Sun as an energy source is difficult' (Hottel 1978). Putting it another way, 'Where it is a duty to worship the Sun it is pretty sure to be a crime to examine the laws of heat' (Morley 1948), and perhaps one might add the laws of economics.

The Sun's rays arriving at the Earth's surface provide a very diffuse amount of energy. Flat-plate solar collectors receive heat at an average rate of between 25 and 90 W/m^2. In a modern boiler furnace the heat transfer to the water walls is of the order of 100 kW/m^2. A windmill or aerogenerator can produce up to 50 W/m^2 of disk area in a 8 km/h wind, but of course, this is work and not heat. A single row of blades in the last stage of a modern steam turbine develops some 1 MW/m^2 of disk area.

A method of estimating the amount that it is worth investing in solar energy schemes is presented in figure 1 which shows the present value of the total fuel saved in a number of years as a multiple of the annual value of the fuel saved. If 1 m^2 of solar panel can for instance save £10 per annum of fuel over a 15 year period, then at a discount rate of 10% the present value of the fuel thus saved is £76. Current figures suggest that installed solar panel equipment costs some £150 per square metre.

These figures illustrate a major difficulty in the use of solar energy, and present a challenge to our ingenuity.

References (Hawthorne)

Hottel, H. C. 1978 The reach of economic and technological assessments of solar energy, *1st International Conference on Energy and Community Development*. Athens, Greece. July 11.

Morley, John (Viscount) 1948 on Voltaire, *Familiar quotations* (ed. John Bartlett), p. 64. Boston: Little Brown & Co.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES