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The human brain evidently evolved to commit itself emotionally only to a small piece of geography, a limited band of kinsmen, and two or three generations into the future. To look neither far ahead nor afield is elemental in a Darwinian sense. *We are innately inclined to ignore any distant possibility not yet requiring examination. It is, people say, just good common sense.* Why do they think in this short-sighted way?

The reason is simple: it is a hardwired part of our Paleolithic heritage. For hundreds of millennia, those who worked for short-term gain within a small circle of relatives and friends lived longer and left more offspring — even when their collective striving caused their chiefdoms and empires to crumble around them. The long view which might have saved their distant descendants required a vision and extended altruism instinctively difficult to marshall.

The Future of Life, by Edward O. Wilson 2002.

The Optimum Population Trust (UK): Manchester

<www.optimumpopulation.org>

INTRODUCTION

Martin Desvaux has now reached Chapter 15 in his synopsis of Clive Ponting's great book, *A Green History of the World*. The chapter *Creating the Affluent Society* addresses a major problem that presses upon the world today. Martin continues to survey the first edition of the book; soon he will be looking at the revised edition published in 2007.

Next is a lengthy paper (pp. 6-17) which addresses the fundamental objective of the OPT Journal, namely to establish carrying capacities for various nations. This paper tackles the UK, which is somewhat easier than either the USA or Australia, both of which suffer from uncertainty about sustainability, mainly because of their reliance on irrigation. The article is a rather long logical slog, but there is no escaping either the fact that energy problems lie at the core of the carrying capacity problem, or that *types* of energy have to be considered, introducing unavoidable complication. My thanks go to Martin Desvaux, David Pimentel, and Eric Rimmer for having joined me in the long logical slog.

An interesting fact to emerge from this detailed analysis is how closely it agrees with our usual calculations based on eco-footprinting. In fact, based on the same energy usage and without counting the benefits of fishing grounds (maybe not sustainable), and using *Living Planet Report 2006* as the data source, we arrive again at a carrying capacity for the UK of 16 million. Such exact agreement must be chance, because accuracy to within a few million is lacking, but arriving at even approximately the same result provides a useful confirmation of eco-footprinting methodology.

Along with *Green History*, David Willey and I always put the book *Food, Energy, and Society* by David and Marcia Pimentel right at the top of the list of OPT's most important books. The first edition of the book appeared in 1979, but its relevance has only grown with time, and in 2007 the 3rd edition was published. Here I embark (pp. 20-21) on the first of a series of extracts from the 3rd edition.

Nothing engages more powerfully the astonishing power of unreason enjoyed by most humans, than the subject of population! Thus when the enormity of the problems engendered by overpopulation become hard to refute, most people take refuge in the thought that nothing can be done about it anyhow. On pp. 22-24, we look at what could be done about it if only one could thwart the many forces that demand perpetual growth.

A popular objection to a shrinking population is that it would produce huge difficulties in terms of supporting the elderly. On pp. 25-26, Brian McGavin addresses this shibboleth.

Ted Trainer has been mentioned in the OPT Journal many times, for instance, within a piece titled *The Social and Ecological Consequences of Globalization* (p. 24 Vol. 3/1); in the course of noting six dire world problems, one paragraph therein reads:

> Globalization introduces much insecurity into the lives of most people. … The full effects of this unfortunate situation have been admirably described by Ted Trainer in a series of book, culminating in his latest book *Towards a Sustainable Economy* (1996).

In his latest book, *Renewable Energy Cannot Sustain a Consumer Society*, Ted continues to point out the fallacies of conventional thinking. On pp. 27-28 we take a look at it.

Erratum: On page 11 in the last issue of the OPT Journal, Volume 8/2, four lines into the Conclusion, a correction error occurred: instead of reading "much less that the 18 hectares needed to provide horse power," it should have read "less that the 7 hectares needed to provide horse power," thus agreeing with the figure given twice in the earlier text.

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CLIVE PONTING'S *A GREEN HISTORY OF THE WORLD.* Part 7

A synopsis by Martin Desvaux PhD CPhys MInstP

"With the greater part of rich people, the chief enjoyment of riches consists in the parade of riches, which in their eye is never so complete as when they appear to possess those decisive marks of opulence which nobody can possess than themselves." *Adam Smith*

Chapter 15: Creating the Affluent Society

> Since the rise of settled societies some eight to ten thousand years ago the majority of the world's population has lived in conditions of grinding poverty. They have had few possessions … and have been forced to spend most of their limited resources on obtaining enough food to stay alive. Although in all societies the elite have lived at a higher standard than the overwhelming mass of population, they too only had access to a very limited range of goods and services for most of human history. However in the last two hundred years a sizeable minority of the world's population has achieved a standard of living that would have been unimaginable for previous generations. But this relatively sudden and recent improvement has been obtained at a significant price – a vast increase in the consumption of the world's limited energy resources and raw materials, widespread pollution from the industrial processes involved and a variety of social problems.

Because of their mobile lifestyle, hunter-gatherers place little value on possessions and keep them to a minimum. In settled societies it becomes necessary to own goods, and to store and process food it is necessary to collect chattels. Until 1800, societies were predominantly agricultural and most of the population lived a hand-to-mouth existence by being continually at the mercy of the climate and food supply: *"... about 80 per cent of expenditure of the mass of the population went on food but the diet was still poor ... Even in relatively prosperous times people might have no more than ten per cent to spend on clothing ... Once food and clothing had been provided for, very little money was left for housing. The average peasant hut was made out of wattle and daub, with an earth floor, no windows or chimney and cooking was on a spit or a pot over an open hearth."*

The relatively few rich spent most of their income on housing and enjoyed better clothing, education and food – usually prepared and served up by slaves/domestic servants. In rural areas, people were at the mercy of the climate, while in cities overcrowding and abject poverty were rife: *"Most people, though, lived either in a state of destitution or on the edge of it. They had no savings and so the slightest problem such as illness or unemployment would reduce them to starvation and begging…Official returns in Florence in 1457 showed that 82 per cent of the population were classified as either poor or destitute."* Elsewhere in Europe, people fared little better over the next 400 years. In England, from the mid-19th century, things improved gradually. Even so, housing and sanitation were such that 8 per cent of the population was officially designated as overcrowded in the census of 1901. These overcrowded conditions derived from need to expand industry.

Heralding the evolution of plastics, artificial fibres – mainly rayon and cellulose – were developed in the late 19th century and were being mass-produced before 1914.

> By the late nineteenth century the industries that had formed the backbone of the first wave of large-scale industrialisation were beginning to stagnate … New industries that formed the second wave, such as chemicals derived from organic materials, electrical engineering and car production …were the key to continued growth in output in the first part of the twentieth century.

Production increased during the inter-war years and, combined with the development of nylon post WWII, the plastics industry exploded: "*After 1945 ... world production of plastics has, on average, doubled every 12 years. By the 1970s it exceeded the combined production of aluminium, copper, lead and zinc, and per capita consumption had increased by over one thousand per cent since 1945.*"

The latter half of the 20th century saw rapid growth of a new wave of electronics, computers and communications industries spawning *" …an ever-increasing, indeed almost bewildering, variety of products that industry can conceive, design and persuade the public to buy. The technology and machinery involved have often been highly sophisticated, but the basic inputs remain what they have always been … a huge increase in energy consumption (especially coal and oil) and the use of ever greater quantities of metals."*

Nowhere is the increasing use of materials and energy so clear as in mining. Early metal production started with smelting lead (6400 BC), followed by copper (3700 BC) which in turn led to tin and the alloy, bronze. Iron, much more difficult to process, eventually gained a foothold around 1200 BC, its production spreading gradually over Europe, China and the American colonies reaching around 300,000 tons by 1700. Worldwide production of iron and steel then grew to 12 million tons by 1850, increasing another one hundred-fold by 1980. Similar magnitudes of growth occurred for nickel, manganese and aluminium, but not without serious costs to the environment:

> About 70 percent of the world's ore (95 per cent in the United States) is obtained by the most environmentally damaging of all methods – open-cast mining. This keeps down the cost, but involves the digging of vast pits or the removal of whole mountain tops, the destruction of topsoil and the creation of large amounts of waste. This waste … can cause rivers to silt up and valleys to be filled in, it is often toxic and therefore creates an uncultivatable desert or leaches into water courses and poisons them.

As the richest seams became depleted, new ones were opened up. With improved extraction methods lower yield ores could be processed, generating even larger quantities of waste (slag) as previously depleted rich sites were revisited.

Downstream, energy production and wealth increased. In the market place, this took the form of the development of retail outlets; a few specialised clothing, jewellery and instrument workshops became established in major cities in the 1600's. Until the late 1800s, food was only sold at markets, but since 1900, shopkeepers, selling goods made by others, appeared and initiated the evolution of chains, department stores, supermarkets and hypermarkets. In the 1920s, the consumer durable boom started in America leading ultimately to the availability of all manner of convenience products such as refrigerators, washing machines, etc. This consumer boom eventually led to a virtual saturation of the market with products; to continue growth, manufacturers had then to develop new products, improve old ones and build in obsolescence to exploit the consumer market. The most expensive of these products was the motor car; *"Across the world the ownership of cars and light trucks rose from 50 million in 1950 to just over 400 million by the 1980s …"*

Increase in wealth brought with it spending power which entrepreneurs were eager and quick to satisfy. Sport – in particular football, boxing, cricket, etc. – became big business. Holidays became longer and more frequent, leading to world travel and tourism through a host of tour operators, hotels, caterers, holiday camps and cruises. Growth of easy credit for consumer goods fuelled evolution of multinational corporations with the power to control purchasing trends. Changes in fashion and built-in obsolescence encouraged people to throw away and buy anew with scant regard for the environment. An offshoot of this mentality has been the growth of conspicuous consumption to demonstrate wealth, noted by Adam Smith in the title quote (above). Rising expectations were a strong feature of the developing affluence as state-funded primary education, as well as insurance, housing, pension and health care schemes became established throughout the 20th century.

On the subject of cars, Ponting notes that: *"The history of the motor car in the twentieth century reveals the transition from great expectations to major environmental problems."* He highlights the power and irresponsibility of the growing corporations in the United States as they eliminated competition: *"… the car industry decided not to leave the decay of public transport to the vagaries of the market system and instead took action to close down the public transport systems and force people to use cars. In 1936 … General Motors, Standard Oil of California and the tyre company Firestone formed a new company called National City Lines whose purpose was to buy up alternative transport systems and close them down."* Twenty years later, over one hundred rail systems in 45 cities had been removed, the largest of which was "*the Pacific Electric System, which carried 110 million passengers in fifty-six communities. … by 1961 the whole network was closed."* The consequences for the environment are clear when one considers that, compared to rail, car transport consumes six times the energy per passenger mile and the infrastructure consumes three-and-a-half times more and uses four times the land area.

Transport spawned tourism. "*The eight-fold increase in international tourism in the last forty years has severely strained facilities and even destroyed the original attraction of the places that people came to see …* [and Venice] *is now little more than a museum …"*

"*The distribution of wealth in the world became increasingly unequal in the period after 1500.*" Wealth from the colonies gave a few nations substantial control over the world's resources. The commitment of international aid since 1950 has failed to improve matters:

> In 1950 the per capita wealth of the poorest countries … was about four per cent of that of the industrialized nations, by 1980 that figure had fallen to two-and-a-half per cent. … In Britain in the 1980s the proportion of national income going on aid actually fell from 0.52 to 0.32 per cent … Most aid from the United States has gone to those countries judged to be of military and strategic importance and Britain's aid programme has paid for a £7 million hospital in the Falkland Islands and an £18 million naval repair yard in Gibraltar.

Ponting illustrates how multinationals benefited from World Bank funding of major construction projects, while millions of locals suffered displacement and disease as a result. Dams, in particular, were frequently a failure due to a combination of high local evaporation rates and deforestation which, *"… produces a very high run off and siltation rate … in China the Sanmenxia dam, which was completed in 1960, had to be abandoned four years later because the reservoir had silted up and the Laoying project even had to be abandoned before it was completed for the same reason.*"

Ponting's summary of the development of affluence up to 1990 makes the picture clear:

> For the last eight or nine millennia settled societies have produced inequalities in wealth, but the differences were essentially internal. Before the expansion of Europe and the intensification of industrial output there were no major differences in wealth between the main agricultural societies themselves. The emergence of an affluent society has not changed the persistent historical fact of internal inequality (despite major changes in the standard of living for all the inhabitants of the industrialised world), but it has brought about a huge shift in the pattern of wealth distribution worldwide. Domination of the international economic system has enabled the industrialised countries to utilise the vast majority of the world's resources and develop unprecedented, high levels of consumption. One part of the world can now be dubbed 'affluent', while the great majority of the world's population still live, as they always have done in the past, in conditions of absolute poverty. The changes that opened the way to the higher levels of consumption also involved social and environmental penalties, some of which, notably a big increase in the amount and sources of pollution, are now affecting the whole world.

LIMITS TO POPULATION IN A UK RELIANT ON RENEWABLE ENERGY

by Andrew R.B. Ferguson

Abstract: On the basis of present knowledge concerning sources of renewable energy, there is compelling evidence that a population of 16 million, at most, could be supported in modest comfort in the United Kingdom. The problem arises mainly on account of the low power density of renewable energy sources, and partly due to the uncontrollability of the output of those with higher power densities. The extent of the problem becomes apparent when the difference between *types* of energy is taken into account. The analysis is made on the basis of using a form of liquid energy, from renewable sources, requiring about the same amount of energy input to grow, harvest and convert to liquid as the energy contained in the liquid; this is substantially the situation that obtains today.

1.0 Liquid fuels

The importance of assessing energy inputs when growing food or producing biofuels was brought to public attention with the publication of the first edition of *Food, Energy, and Society*, in 1979.[1] By 2002, the US Department of Agriculture's report, *The Energy Balance of Corn Ethanol: An Update,*[2] was able to include nine previous studies of estimates of energy balances related to producing ethanol from corn (maize). Whether many of them got close to the truth is another question, but the importance of the issue was clearly understood.

However, to my knowledge, the only scientists who put much stress on the *power densities* being achieved when growing biofuels were Howard Hayden[3] and Vaclav Smil.[4] But they were merely using the data that had been gathered by others, and there is a serious flaw in assessing power densities (the amount of useful energy captured per year from a specified area of land) on the basis of the previously mentioned energy balance analyses. While such analyses distinguish between heat energy and electrical energy (which requires nearly three times as much fossil fuel energy to produce), they rarely differentiate energy in the form of liquid fuel. This oversight is understandable. If you want to heat your house, there is not much to choose between using oil, gas, coal, or wood, except for cost differences. But to heat your house with a liquid fuel made from renewable energy sources would be madness, since, because of losses in the conversion process, the fuel would contain only a third of the energy present in the original biomass; moreover a considerable amount of energy would have been expended in producing it. *It is only in the context of a renewable energy world that it becomes necessary to treat liquid fuel separately and thoroughly*, because it affects all other components of the analysis. This paper is an attempt to get to grips with that problem.

To avoid getting waylaid with relatively insignificant uncertainties about controversial 'facts' concerning yields, etcetera, we will first do a rough hypothetical assessment, and then later consider how large might be the errors arising from such approximations.

1.1 A first rough assessment of the power density of liquid fuels

As a hypothetical example of liquid fuel produced from biomass, we will posit a yield of 2000 litres per hectare. For comparison, figures from processes that are actually being used are: about 3900 litres of ethanol per ha from sugarcane in Brazil, 3200 litres of ethanol per ha from corn (maize) in the USA , and 520 litres of biofuel oil per hectare from soybeans in the USA. It is doubtful that any of these crops are sustainable, since all of them are associated with high rates of soil erosion.[5]

For this hypothetical liquid fuel, let us assume an energy density of 25 megajoules per litre (MJ/L). For comparison ethanol is about 21 MJ/L, methanol 16 MJ/L, and an average figure for biodiesel is 36 MJ/L.

The amount of fluid we have posited, 2000 litres from one hectare (a gross yield), would thus provide 2000 x 25 MJ/ha/yr = 50 gigajoules per hectare per year (GJ/ha/yr). This is more easily visualized as a power density of 1.6 kW/ha (to visualize it, imagine 16 light bulbs on continuously, each rated at 100 watts, placed within that one hectare, 10,000 m^2).

1.2 A first approximation to the ecologically productive land needed for liquid fuels

Each UK citizen uses about a mean 5 kW (= 43,800 kWh/yr) of primary energy,[6] and of that about 32% (1.35 kW/cap) is petroleum. However, looking into the future, to a time when energy is scarce, and energy economy has to be practiced, we may assume that each citizen will use far less energy; let us assume 2 kW per person. Because liquid fuel is hard to produce, we can imagine exceedingly frugal use, so let us say that each person uses, directly and indirectly, only 0.3 kW of energy in liquid form (about 20% of present use). Thus at the aforesaid power density of 1.6 kW/ha, each person would need 0.3 / 1.6 = 0.19 hectares of ecologically productive land to supply the liquid fuel they use directly and indirectly (the latter in the form of goods and services purchased).

With the present population of 60 million (60 M) people in the UK, the amount of ecologically productive land needed would be 0.19 x 60 M = 11 million hectares. This represents about 60% of the 18 million hectares (18 Mha) of ecologically productive land that exists in the UK. As this requirement is in addition to that needed to produce food, it is already apparent that the problem is very severe. Yet that 60% is only a first approximation to the analysis, because we have yet to consider the inputs needed to produce the liquid fuel.

1.3 A more refined assessment of the power density of liquid fuels

The liquid fuel analysis involved a fair bit of complexity. Hopefully Figure 1, p. 16, will facilitate comprehension. The **[S..]** symbols in the text below are another aid, and can be cross-checked against similar numbers on Figure 1.

In attempting to decide whether any liquid-producing energy crop is worth growing, it is necessary to look at the yield of liquid *net* of the inputs. What is normally (and correctly) done in assessing those inputs is to ignore the energy contained in the feedstock (e.g. the sugarcane, corn, or wood), since this shows up in the amount of land used to produce the energy. What needs to be analysed is the energy required to sow, tend and harvest the feedstock, plus all the other inputs that are needed to produce the desired liquid output, e.g. a distillation plant. A common way to express the results is in terms of the output to input ratio (the energy return ratio). For example, it may be expressed as 1.4:1, or an energy return ratio of 1.4, which would mean that the liquid fuel output has a calorific value that is 1.4 times the inputs required to sow, tend and harvest the feedstock, transport it to a production plant and then produce the ethanol.

Considerable work has been done with regard to ethanol, so taking that as a general guide, it is about right to assume that 220 litres of gasoline or diesel fuel is needed per hectare, for the whole process (with the exception of one item to be mentioned later) of growing the crop, feeding it, harvesting it, and transporting it to a refinery to produce the ethanol. Since 220 litres in the form of gasoline is about equal to 290 litres of our hypothetical liquid,[7] these liquid input requirements produce a *partially net* yield of 2000 - 290 = 1710 litres per hectare per year = 43 GJ/ha/yr = 1.36 kW/ha.

But there are many other inputs that need to be liquid in form besides the ones just considered (such as for transport, which must obviously be liquid). For example, inputs are needed to produce nitrogen, phosphorus and potassium fertilizers, and for seeds, insecticides and herbicides. There are other such inputs related to providing ancillary equipment, such as tractors, transport vehicles, sheds, distillery plant (suitably amortized over their lifetime). The conventional way to deal with such inputs is to use a source like Boustead and Hancock's *Handbook of Industrial Energy Analysis (*1979),[8] which gives data about the energy needed to produce a kg of steel, a cubic metre of cement, etc. However such data sources do not divide the energy required into *heat* energy and *liquid* energy. Thus we can only arrive at a simple energy budget comprising an unknown balance between liquid and heat. Yet it clearly makes little sense to subtract the heat input from the *net* liquid output, for it would tell us little. For example, the output may be considerably less than the input, but that does not mean that production of the liquid fuel is useless. That is clear from electricity production: we use about 100 GJ of coal energy to produce about 35 GJ of electricity, because currently we value the smaller amount of electricity more than the larger amount of heat energy in the coal. On a similar basis, it might be appropriate to produce this hypothetical liquid, even though the energy in the inputs considerably exceeds the energy in the liquid output. Additional land would have to be used sustainably to produce the inputs needed. The cost of so doing is to use more ecologically productive land in the overall process of producing the liquid.

What may ultimately put a stop to producing such fuels, as we will see, is the extent to which additional inputs reduce the already low power density. The 290 litres of hypothetical liquid mentioned earlier represents about 15% of the input. There is a requirement for yet another input, nominally as 'heat', amounting to a further 85% of the input (the total calorific value of input and output is about the same). We noted that the gross output of liquid was 1.6 kW/ha; so the 'heat' input required is about 0.85 x 1.6 = 1.35 kW/ha.

In reality this additional 'heat' input is not itself entirely heat. What we are concerned with now is steel, cement, tractors, and the actual transport vehicles; that is the actual hardware, and also fertilizers, herbicides and pesticides. For instance, steel requires ores to be mined and taken to places where the iron can be made into steel. The steel then needs transporting to factories where products are made.

As observed, the figures given by Boustead and Hancock do not distinguish between the types of input required, but to see what would be involved in a fully relevant analysis (testing adjustments later), let us assume that the liquid input needed comprises 20% of the whole 1.35 kW 'heat' input that we just calculated as being required per hectare, i.e. 0.20 x 1.35 = 0.27 kW/ha [S2]. That leaves a demand as actual heat input of 0.80 x 1.35 = 1.08 kW/ha [S3].

Dealing with the actual heat input first, it is within the bounds of possibility, at least in some places and probably needing some fertilizer, to obtain a yield of 8 dry tonnes per hectare from short-rotation woody crops. That amounts to 160 GJ/ha/yr = 5.1 kW/ha. Thus to obtain the 1.08 kW needed as heat input for growing and processing 1 hectare of crops would require the harvest of 1.08 / 5.1 = 0.21 hectares of woody crops.

Returning to the liquid fuel input requirement established above as 0.27 kW for each hectare. 0.27 kW/ha is equal to 8.5 GJ/ha/yr, and with the energy density of the liquid fuel output being 25 MJ/L, this could be provided by 8500 / 25 = 340 litres of liquid fuel. Thus our *revised net* output of liquid fuel is 1710 - 340 = 1370 litres/ha/yr [S4].

We can now estimate the 'fully *net*' energy capture, since we have (a) a *net* 1370 litres/ha/yr (= 34 GJ/ha/yr = 1.09 kW) of our hypothetical liquid fuel being produced, and (b) the land area needed to produce it, namely the 1 ha of cropland + 0.21 ha to grow the woody crops. This makes the 'fully *net*' power density 1.09 / (1 + 0.21) = 0.90 kW/ha.

1.4 A more precise estimate of the ecologically productive land needed to produce liquid fuels

Having established something close to the real power density of the liquid fuel, we can revise the first rough estimate. This was that 60% of the total area of ecologically productive land in the UK was needed to provide 60 million UK citizens with 0.3 kW of liquid fuel. The refined estimate we can now make is that to provide each person with the posited 0.3 kW would require 0.3 / 0.90 = 0.34 ha/cap. Thus 60 million people would require 60 x 0.34 = 20 Mha, which is 1.1 times the total area of ecologically productive land in the UK.

It should be noted that 'fully net' was placed in apostrophes above, for even this analysis does not provide a complete analysis; the woody crops are not going to magically harvest themselves and convey themselves to where they are needed to provide heat! A complete analysis would therefore have taken into account the further liquid fuel and the ancillary equipment needed to harvest the heat source, and take it to where it is wanted. However data covering these matters are somewhat uncertain; and the reader may be pleased that I am not going to further complicate the liquid requirement part of this analysis!

2.0 Using uncontrollable energy from renewable sources

Table 1, p. 14, may be helpful in keeping track of the many steps that now follow. The 0.34 ha/cap deals only with the 0.3 kW of *liquid* fuels with which we are hoping people can manage. Let us continue by assuming that a further 1.2 kW per person is required for heating and manufacture, etc. Note that the total of 1.5 kW/cap is still only about 30% of present per capita energy consumption in the UK; however, as we shall see, the 1.5 kW involves a requirement for more primary energy.

Although 'uncontrollable' energy sources such as wind turbines and photovoltaics have a far higher power density than liquid fuels, or even woody crops (at least by some measures, as will be made clear later), it probably would not make sense to provide all heating from electricity. So we need to partition the 1.2 kW per person into electrical energy and heat energy. It would be in the ball park to make a 3 to 9 partition, i.e. 0.3 kW electricity and 0.9 kW heat, the latter being, for example, provided from woody crops.

Let us select wind turbines for this study as being representative of uncontrollables, because electricity from wind turbines is not only cheaper than electricity from photovoltaics, but the achieved capacity factor is higher than photovoltaics (in better wind areas about 35%, compared to 20% even in a very sunny site like Arizona).

2.1 Assessing the power density of the uncontrollable output of wind turbines

For purposes of this analysis, let us take a 3 MW wind turbine (although the size does not matter), and assume it operates at a 30% capacity factor, which would thus deliver a mean 0.9 MW, i.e. a mean 900 kilowatts (kW). The space actually occupied by wind turbines is only 2–5% of the protected area they need. Each MW of capacity requires about 25 hectares of protected area around it, so a 3 MW turbine would require 75 hectares. But as some of the turbines would be offshore and others on barren hill tops, let us take the lowest figure of 2%, in which case the 3 MW turbine uses, on average, 75 x 0.02 = 1.5 ha of ecologically productive land.

The energy return ratio (output/input) of wind turbines is hard to establish, since no one has gathered the data needed to make the calculations involved in (a) accounting for the inputs needed to build the high voltage transmission lines required to deliver the electricity, and (b) the embodied energy in the power backup that has to be provided because of the variable nature of the output (this backup is in fact mainly made available by operating the controllable plant at a reduced capacity factor).

There are further complicating factors about what energy value to ascribe to the electrical output, but we will not dwell on that, and merely say that it will be close enough to consider the energy return ratio for wind turbines, including their associated transmission and backup, to be 8 to 1; i.e. the required input is 1/8th of the output (a figure which may be either too high or too low according to various estimates). This covers the installation and maintenance of the wind turbines and the need to mine and transport ores to manufacture the wind turbines. This time, unlike when assessing liquids, we will be doing an all-in-one analysis of the liquid inputs needed.

It is convenient to divide up the required input into 50% heat, and 50% liquid fuel at this stage. We can consider the effect of a different assumption later (see Objection 8).

The 50% required as heat, some of which will probably need to be electricity anyhow, can conveniently be regarded as being provided by the wind turbines. Thus having made use of 1/16th of the output as input, we are left with a *net* 15/16 x 900 = a mean 844 kW of electricity (from this 3 MW capacity wind turbine).

For the further 1/16th required as liquid fuel, we can use the earlier calculation that showed the *net* power density for liquid fuel to be 0.90 kW/ha. Thus the area needed is (900 / 16) / 0.90 = 63 ha. This gives a *net* power density of 844 / (1.5 + 63) = 13 kW/ha. Thus it is clear that, as stated earlier, the power density, measured in terms of the uncontrollable output, is considerably better than biomass, which for short-rotation woody crops we somewhat optimistically put at 5.1 kW/ha.

2.2 Assessing the power density of the uncontrollable output of wind turbines when it has been smoothed by the use of controllable input

The big problem with uncontrollables is their uncontrollable nature. There are two ways to estimate how much wind turbines can contribute to delivering power:

a) In delivering steady power, the controlling factors are the peak infeed from the system,[9] which is usually about 80% of capacity, and the capacity factor, which we have assumed to be 30%.[10] With these parameters, the wind can supply 30/80 = 38% of the power, while controllables will have to supply the remaining 62%, in order to produce a steady output.

b) This is flattering to wind turbines, because consumer demand is not steady. If fluctuating demand is to be satisfied without storage, it is fairly easily demonstrated, and generally agreed, that wind turbines can only provide about 20% of the total electrical energy.[11]

Which of these two should we choose? In the meagre energy future we have in mind, we can perhaps plausibly suppose that great efforts are made to encourage people to increase their demand in times of normally low demand, e.g. by using night storage heaters, and to avoid using electricity at what would otherwise be times of peak demand — perhaps by high pricing. Therefore it would be an acceptable approximation to say that, in a meagre energy future, the situation is closer to (a) than to (b), i.e. we can assume that energy demand will be fairly flat. Thus we will make the favourable assumption that wind can supply 38% of the 0.3 kW of electricity with which we aim to provide each person.

Thus the electricity will be supplied as: (i) 0.38 x 0.3 = 0.11 kW/cap as electricity from the wind turbines, with (ii) the remaining 0.3 - 0.11 = 0.19 kW/cap from controllable sources.

The first choice for balancing power will be hydroelectric output, since it can be varied rapidly, and is therefore an ideal controllable source to balance wind variations. But to introduce hydroelectric power into the calculation, we need to look at the total electrical demand.

Based on our assumption that each person needs 0.30 kW of electricity, total electrical demand would be a mean 0.30 x 60 M = 18 million kW. This electrical power will be supplied as (i) 0.38 x 18 = a mean 6.8 million kW from the wind turbines; plus (ii) 18 - 6.8 = a mean 11.3 million kW from controllable sources. Using the previously calculated power density of 13 kW/ha for the uncontrollable output of wind turbines, it will require 6.8 [M kW] / 13 [kW/ha] = 0.51 Mha of ecologically productive land to provide the electricity for item (i). In per capita terms this is 0.51 / 60 = 0.009 hectares.

Turning to item (ii), as already mentioned, the first choice is hydroelectric power. Delivery of hydroelectricity in the UK varies from year to year, but the average for 2000-2004 was 5680 billion watt hours, which is a mean power of 0.648 million kW. By using this we can reduce the need for other controllables from 11.3 million to 11.3 - 0.648 = a mean 10.6 million kW.

Let us suppose that this remaining controllable power to balance the wind turbines comes from short-rotation woody crops. Supplied in the form of wood, the power density is 5.1 kW/ha. However, burning wood to produce electricity is only about 25% efficient, so in delivering electricity, the power density is 5.1 x 0.25 = 1.27 kW/ha. So to provide the remaining 10.6 million kW of electricity will require 10.6 / 1.27 = 8.4 million ha of ecologically productive land, or 8.4 / 60 = 0.139 ha/cap.

Thus the total area needed to provide the desired 0.3 kW of electricity is 0.51 + 8.4 = 8.9 Mha. That amounts to 8.9 / 18 = 0.49 times the available ecologically productive land. In per capita terms each person requires 8.9 / 60 = 0.148 hectares to provide electricity (also calculable from above as 0.009 ha/cap + 0.139 ha/cap).

It will be useful to note that the overall power density that is achieved for *electricity* delivery, based on ecologically productive land used, is (0.3 x 60) / 8.9 = 2.0 kW/ha, which is certainly better than the 0.89 kW/ha achieved for liquid fuels.

For later use, we should also note that because of the conversion being only 25% efficient, to produce the above mentioned mean 10.6 million kW of electricity from controllable sources (woody crops), 10.6 / 0.25 = a mean 42.4 million kW of primary energy had to be used. Thus 42.4 - 10.6 = 32 million kW was 'lost' in conversion. That amounts to 32 / 60 = 0.53 kW/cap. To correctly assess the amount of primary energy being used per person, that amount has to be added to what is actually delivered for use — a matter we will attend to later.

3.0 Providing 0.9 kW of heat per person

In the previous section, we noted that for uncontrollable output an apparently attractive 13 kW/ha can be achieved. But this is diluted by the need for controllable output to work in harness, diminishing the power density to 2.0 kW/ha. So it seems fairly clear that for heat we will be better off supplying the heat from wood directly, at 5.1 kW/ha, which gives full control over when we use it (instead of having to take a share in an enforced steady electrical power). It has to be admitted that the wood stoves that will burn the wood are unlikely to be much more than 50% efficient, but even then, direct use of the wood has an edge over using 'restricted delivery' electrical power. So we can continue the analysis on the basis of providing the required 0.90 kW of heat at a power density of 5.1 kW/ha. That would need 0.90 / 5.1 = 0.177 ha. To provide 60 million people would require 11 Mha, which is 60% of the available ecologically productive land.

Before moving on to the next section, dealing with food and forest, we can total up the ecologically productive land requirements to provide *energy* as: 0.34 (liquid fuel) + 0.009 (to provide electricity directly) + 0.139 (to provide electricity via woody crops) + 0.177 (to provide heat) = 0.66 ha per person. For a population of 60 million, that would require 0.66 x 60 = 40 Mha, which is 2.2 times the area of ecologically productive land currently available in the UK. It is also of interest to look at the overall power density achieved in the task of producing energy (in terms of ecologically productive land). It is (1.5 x 60) / (2.2 x 18) = 2.27 kW/ha. And making use of an earlier observation that 0.53 kW/cap of primary energy got 'lost' in conversion to electricity, we can also take note of the fact that we are hypothetically supplying each person with 1.5 + 0.53 = 2.03 kW of energy (as originally intended in fact). That datum also gives us the power density that has been achieved; it can be assessed as (2.03 x 60) / (2.2 x 18) = 3.1 kW/ha; as a matter of interest, it so happens that that is approximately the power density used in eco-footprinting.

4.0 Providing food, forest products, and biodiversity

Another form in which 'energy' must be supplied is food. At present, the UK grows only enough food to feed about 60% of the population. Thus to feed the entire population, we would need 1 / 0.6 = 1.67 times the ecologically productive area we presently have. It might be objected that we could change some of our forest area to cropland and pasture, but in fact we currently only supply ourselves with about 20% of our forest products,[12] so the 1.67 times figure suggested is an underestimate, because an even greater expansion would be needed to fully satisfy our demand for forest products, e.g. for timber and paper, and of course some ecologically productive land is needed to preserve biodiversity, and it is dubious we have enough of that. It is of interest to note, too, that the ecologically productive land that is hereby being suggested as needed to provide food, forest products, and provide for biodiversity is (18 x 1.67) / 60 = 0.5 ha per person. While this figure may be all right for the UK, in the USA the requirement for *cropland alone* works out at 0.5 ha/cap. The main reason is likely to be that more meat is eaten in the USA; the livestock population consumes about seven times as much grain as the human population.[13]

5.0 The overall situation

We can now review the overall situation in terms of multiples of the area of ecologically productive land that is available. The total land needed to support a population of 60 million, with the much reduced power of about 2 kW of primary energy per person, is a multiple of 2.2 (for power) + 1.67 (for food) = 3.87 times the ecologically productive area available in the UK. Thus the population which could be supported, according to these calculations, is 60 / 3.87 = 16 million. To some people that might seem excessively low, but recall that in 1798, when it was apparent to Thomas Robert Malthus that population was a problem, the population of the UK was about ten million. Also, as has been repeatedly stressed, this is a ball park calculation, about which many objections could be raised. To look at such objections will be our next task.

6.0 Objections and questions which need to be considered

An obvious objection to the above analysis is that the ball park estimates are significantly misleading. To show that moderate changes to the parameters chosen do not make a great deal of difference, various "Objections" are raised in the following paragraphs. The objection is given a numbered paragraph, and the paragraphs that follow it provide counter arguments.

1. The figure of 16 million that has been arrived at is low compared to the 26 million figure that OPT quotes as being correct for a "Modest" footprint, yet there should be a closer agreement, because the Modest footprint incorporates a use of energy reduced to the same 2 kW per person that is analyzed here.

   One reason for that is because eco-footprinting methodology counts built-up land as cropland. That produces no distortion when a population is at a sustainable level, but it does when the sustainable population is only a fraction of the existing population. If the built-up land is excluded from the eco-footprinting calculation, the 26 million figure is reduced to 21 million. Another thing which benefits the eco-footprinting results is the use of fishing ground as biocapacity. But we see it as reasonable to exclude the sea in view of the possibility of fishing becoming non-commercial some time ahead. If fishing grounds are also excluded from the eco-footprinting calculation, the carrying capacity with the "Modest" footprint comes down to 16 million. It is likely to be a coincidence that there is such close agreement with the calculation presented here, insofar as neither method can do much more than provide ball park estimates. We, in OPT, still tend to use eco-footprinting, as it is a concept that people are familiar with, but we take the view that the power density used in eco-footprinting, for the energy component, is right almost by good luck, whereas I hope that what is laid out here provides a fairly compelling logical basis.

2. Isn't the 2000 litres per hectare yield that you used for the example rather low? I have heard that yields of about 10 dry tonnes per hectare are possible with switchgrass, and with that, a yield of 4000 litres of ethanol would be expected.

   Switchgrass may be a better choice as corn crops are singularly bad for causing soil erosion — second only to sugarcane in fact. Increasing the yield to 4000 litres per hectare, and adjusting the calorific content of the ethanol to a realistic 21.25 MJ/litre, increases the sustainable population from 16 million to 18 million. Incidentally as soybeans make their own nitrogen, they are a better choice in some ways, but note that the 520 litres of biofuel per hectare that is yielded from soybeans, works out as the equivalent of 520 x (36 / 25) = 750 litres of our hypothetical fuel, so that is far below our illustrative 2000 litres per hectare.

3. I know that you said the 0.3 kW of liquid is about 20% of present usage, but can you give any other indication of what that means in terms of diesel fuel?

   A power of 0.3 kW is equal to 0.3 x 24 x 365 = 2628 kWh per year, which is equal to about 270 litres of diesel. That is very little when you consider that it has to cover all commercial activities, including delivering food to your retail outlet, all services, and even the mining of raw materials, with the exception of those used for producing energy, which we have been dealing with separately.

4. When looking at the production of liquid fuel, you put the fraction of the output that is required as a non-liquid input as high as 85%. There is a good deal of debate about the level of inputs. How much difference would it make if you lowered the non-liquid input to say 65%?

It would make little change. It would only increase the sustainable population from 15.5 (which previously has generally been rounded to 16) to 16.0 million.

5. Would it be possible to cut energy use right down to say 1 kW per person, and if so what population could we support in the UK?

   I don't have historical figures for per capita energy consumption in the UK, but it is estimated that in the USA, prior to 1890, the per capita energy consumption was steady at 3.7 kW/cap.[14] Even in the more temperate climate of the UK, anything below 2 kW/cap looks fairly improbable. Vaclav Smil has argued that 64 GJ/cap/year = 2 kW/cap is a fairly necessary minimum to sustain such things as good infant mortality and moderate educational standards.

   Cutting down to 1 kW/cap would allow a population of 19 million. That figure is not surprising considering that there is a limit due to food alone of 36 million. Of course if we all became vegetarian that would help considerably, but OPT has always aimed at providing estimates of populations that could be supported in a modestly comfortable lifestyle. Actually even in the UK a modestly comfortable lifestyle might be difficult to maintain on the basis of 2 kW per person.

Table 1. Sustainable population of UK when it is reliant on renewable energy					
(a)	(b)	(c)	(d)	(e)	(f)
	Power required.				
		Power density			
			Ecologically productive land (EPL) reqd per person.		
				So EPL reqd for current population.	
Fuel type					Multiple of available EPL.*
	kW/cap	kW/ha	ha/cap	Mha	
Liquid.	0.3	0.90	0.34	20	1.12
Electricity from uncontrollables.	0.11	13.12	0.009		
Electricity from controllables.	0.19	1.27	0.139		
Overall result for electricity.	0.30	2.03	0.148	9	0.49
Heat (from woody crops).	0.90	5.07	0.177	11	0.59
Subtotal (or mean) for all energy.	1.50	2.27	0.66	40	2.20
(mean applies to column c)					
Food, forest products and biodiversity.			0.50	30	1.67
Grand total.			1.16	70	3.87
So sustainable population in millions			16	16	16
* Note: Ecologically productive land (EPL) available in UK is about 18 Mha (from a total of 24 Mha).					

6. It is apparent that if the UK can only produce 60% of the food its citizens consume then to provide food for all, it needs to cut its population from 60 million to 36 million, but let us suppose for a moment that all its food came from abroad, so that all it has to do is supply its citizens with 2 kW of energy, what population could the ecologically available land supply with that amount of energy?

It would allow a sustainable population of 27 million, supposing those nice people abroad continued to feed us! That is an interesting figure, in that it shows that the need for a modest amount of energy is more restrictive than the need for food. At least it is in the way agriculture is carried out at present. It has to be admitted that there has been one large omission in this analysis, namely that agricultural productivity would probably drop dramatically without the advantages of plentiful energy. So in all probability the population estimate of 16 million is too high.

7. It may be an almost impossible thing to run a society on a really erratic electricity supply, but what are the implications of not smoothing out the electrical input from the wind turbines, and just using the input from the wind turbines — posited at 0.3 kW/cap — whenever the wind turbines happen to produce their output?

   0.3 kW/cap is only a fairly small part of the whole, and it would only raise the carrying capacity from 15.5 to 17.4 million. But it would be very difficult to use electricity that way, as input and output must match, so one would have to exercise drastic control over demand, and the prospects of running industry on such an erratic supply are dim. I imagine, too, that a great deal of electricity would be wasted in trying to ensure that demand equated to the variations of supply.

8. One assumption that seemed a bit dubious to me was that the input needed for building and maintaining the wind turbines would be 50% heat and 50% liquid fuels. I wonder how much difference it would make were we to assume 80% heat and 20% liquid fuels.

   It would increase the net power density of the uncontrollable output of the wind turbines from 13 kW/ha to 30 kW/ha, but the uncontrollable output is only about one third of the whole electrical output, and for the same amount of primary energy, it would only increase the sustainable population from 15.5 million to 15.6 million.

9. Supposing that *additionally* to the previous question, we suppose that the process of producing liquid fuels requires only 10% instead of 20%, of what was nominally described as 'heat' input, to be in liquid form.

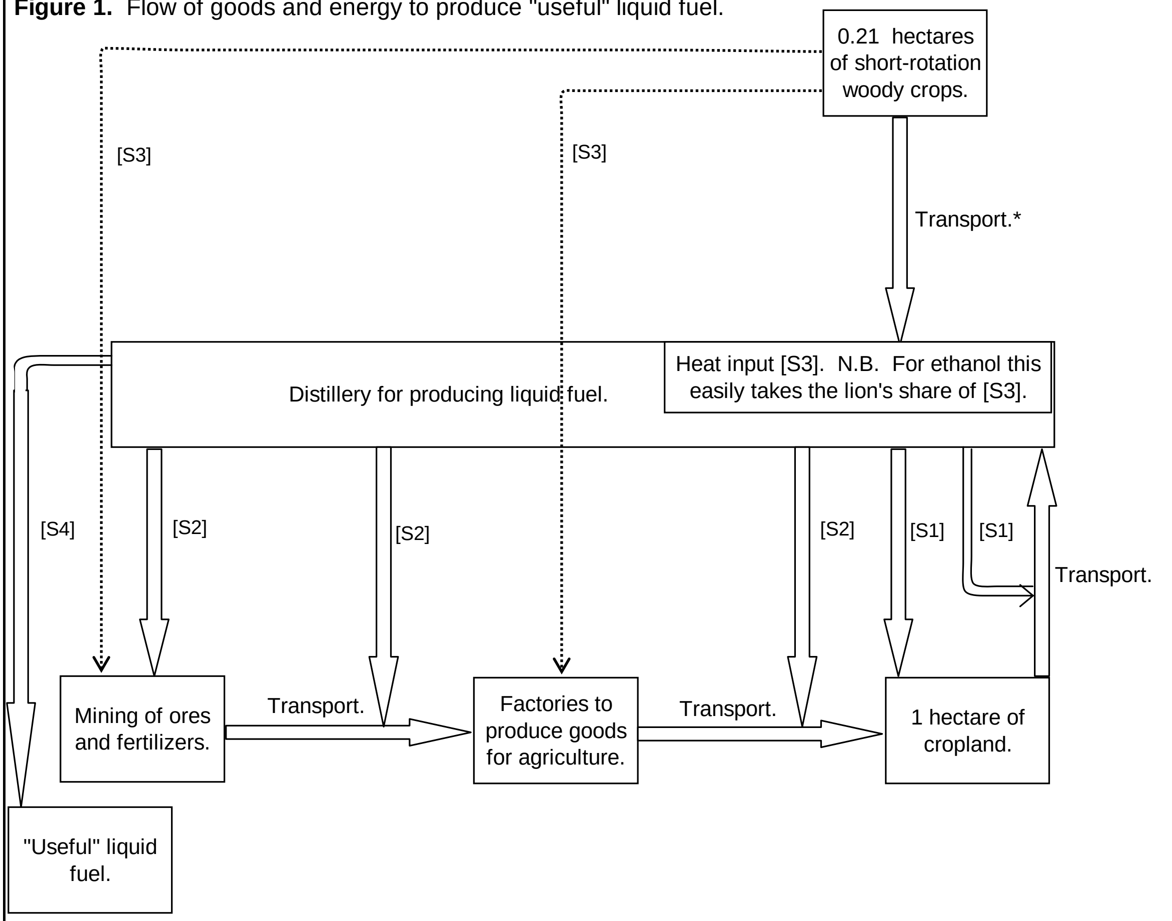
   That would increase the sustainable population from 15.6 to 16.0 million.

7.0 Conclusion

Even in 1979, the time of the publication of the first edition of *Food, Energy, and Society*, it was too late to avoid future disaster. Population and the age structure made some sort of disaster inevitable. But even now we must not abandon efforts to mitigate that disaster. Fossil fuels may virtually run out this century, but many countries have total fertility rates of about 1.3, and if only the politicians and economists in those countries can be brought to see the looming catastrophe, there is still long enough to save millions if not billions of lives by reducing population. Perhaps some countries will even be able to preserve something of the knowledge that civilization has gathered in the last two millennia, instead of moving into a period similar to the Dark Ages.

There is always a *possibility* that science will come up with some new idea that will change the energy picture (although lack of energy is only one problem facing the world), but surely we should not be risking billions of lives on that *possibility*. The human race should not let itself be lulled into a false sense of security by those many academics who casually refer to a time when there will be a "transition" to renewable energy; we should instead ask whether their consoling thoughts belong to the world of reality. The answer to that is only to be found in taking account of all the liquid inputs that would be needed in order to build, install and maintain various plants for capturing solar energy.

Figure 1. Flow of goods and energy to produce "useful" liquid fuel.



* Not only the transport of the woody crops is omitted from the analysis, but also the growing and harvesting of same. As mentioned in the main text, this is just for simplicity.

Endnotes and references

1. Pimentel, D., Pimentel, M. 1979. *Food, Energy and Society*. New York: John Wiley and Sons.
2. Shapouri, H., Duffield, J.A., Wang, M. 2002. *The Energy Balance of Corn Ethanol: An Update*. United States Department of Agriculture (USDA), Agricultural Economic Report Number 813.
3. For the latest edition of Hayden's book, see endnote 14.
4. Vaclav Smil has written many books on energy, all of which put much stress on power densities. One of his most recent books is *Energy at the Crossroads*. Cambridge, Massachusetts: MIT press (2003).
5. Yields are taken from Pimentel, D, Pimentel, M. 2007. *Food, Energy, and Society*. Third edition. Boca Raton, Fl; London; New York: CRC Press, ISBN 978-1-4200-4667-0, and erosion data from Pimentel, D. (Ed.). 1993. *World Soil Erosion and Conservation*. Cambridge, UK: Cambridge University Press. The reasons that soya beans are worse than corn for erosion were given to me in an email by David Pimentel (21 Oct 08): (1) soybeans are a row crop that does not grow very vigorously early in the spring. (2) soybeans do not produce large quantities of residue biomass, compared with corn; (3) the soybean crop residue has large quantities of nitrogen, the soybean vegetation decays rapidly leaving the soil unprotected from rainfall and wind.

6. "Primary" energy is essentially the form in which the energy starts. Thus in the case of electricity from coal or gas, it is the energy contained in the coal or gas. In the case of hydroelectricity it is the energy in the electricity (at least it is usually understood that way, though there tends to be a good deal of confusion!). Energy from uranium is a bit of a problem, as one cannot burn the uranium to see how much energy it has, thus for nuclear electricity the amount of fossil fuel that would be used to generate the electricity is taken as the primary energy equivalent.
7. This assumption agrees closely with the data given on pp. 312-315 of *Food, Energy, and Society* (see endnote 5 for reference), which gives diesel and gasoline for agriculture, plus fuel for transport to the ethanol plant, when added up, as amounting to 15.7% of the gross output. The 290 litres assumed here is 14.5% of the gross output.
8. Boustead, I., Hancock. G.F. 1979. *Handbook of Industrial Energy Analysis*. Chichester, U.K.: Ellis Horwood Ltd (division of John Wiley & Sons, New York).
9. The meaning of "peak infeed" is the greatest input received by all the wind turbines operating collectively, as a percentage of what they would produce if they were all producing at their maximum capacity. E.ON Netz have good data to show that the peak infeed over their 800 km network is about 80%. A valuable analysis by Jim Oswald of Oswald Consultancy Ltd, 7 Dec 2006, for the Renewable Energy Foundation, of winds in the UK, indicated that the peak infeed would be close to 100%. Note that a high peak infeed is a problem. The ideal is to have a peak infeed close to the load factor. The twenty-one page report *25 GW of Distributed Wind on the UK Electricity System*. is available for download on the internet at: http://www.ref.org.uk/images/pdfs/ref.wind.smoothing.08.12.06.pdf A three page commentary on the report is also available on the net in OPTJ 7/2 (pp. 28-30) *The Limits to Wind Penetration in the UK*, at www.optimumpopulation.org/opt.journal.html
10. The amount that a wind turbine can contribute when delivering a steady power, and how this is determined by the peak infeed factor and the load factor, is covered in detail in *A Plain Man's Questions Concerning Wind Power*, pp. 8-12 of *Optimum Population Trust Journal*, Vol. 5, No 1, April 2005. Manchester (U.K.): Optimum Population Trust. Avail.: www.optimumpopulation.org/opt.journal.html
11. The approximate 20% limit on the amount that wind turbines can contribute is covered in "The 20% 'Uncontrollables' Limit," p. 27 of *Optimum Population Trust Journal*, Vol. 6, No 2, October 2006. Manchester (U.K.): Optimum Population Trust. 32 pp. www.optimumpopulation.org/opt.journal.html
12. An approximate estimate from page 71 of Duguid, J.P. 2004. *Population, Resources and the Quality of Life*. Population Policy Press. 108 pp.
13. Pimentel, D, Pimentel, M. 2007. *Food, Energy, and Society*, p. 67 (publication details in endnote 5).
14. Page 20 of Hayden, H. C.. 2004. *The Solar Fraud: Why Solar Energy Won't Run the World* (2nd edition). Vales Lake Publishing LLC. P.O. Box 7595, Pueblo West, CO 81007-0595. 280 pp.

WHY OPT FOCUSES ON OPTIMUM POPULATIONS

by Andrew R.B. Ferguson

Various respected people both within and outside the Optimum Population Trust have suggested that there is now a fairly wide acceptance that populations are too large, so it is time for OPT to move on and start making proposals for tackling the problem. My belief is that these suggestions are mistaken; and I would ask those who are making such proposals to name half a dozen government organisations, NGOs, or media outlets which consistently carry information related to the following vital matters:

1. In the next ten years, it is likely to become indisputable that the petroleum geologists were right, and that there is going to be a *permanent and increasing* scarcity of oil.
2. Within the next twenty-five years, it is likely to become indisputable that there is going to be a *permanent and increasing* scarcity of natural gas.
3. There is fairly good evidence that a *permanent and increasing* scarcity of coal will become apparent within the next twenty-five years.
4. There is fairly good evidence that during the final quarter of this century the availability of all fossil fuels will be less than ten per cent of what it is today.
5. There is good reason to suppose that renewable sources of energy will supply only a small fraction of the energy that is presently available to us (mainly from fossil fuels); and most particularly, it appears likely that there will be a problem with replacing the most vital (for transport) form of fossil fuel, namely one in liquid form.
6. With the above constraints, and others such as climate change, water shortage, and loss of fertile soil, it is unlikely that more than a third of the present world population, and also one third of the present United Kingdom population could be supported in modest comfort.

Negative Population Growth certainly comes up to the mark in recognition of those problems, but I doubt that anyone could think of half a dozen well-known organizations which are trying to convey these vital ideas to the general public. Thus I see the main task of OPT to be to try to ensure that more organizations are giving publicity to these vital long-term issues. Maybe when that has been achieved, OPT could productively turn its attention to discussing the best methods of achieving a downward trend in population during the time that remains before fossil fuels become impossibly scarce. But different methods will be applicable in different countries. Moreover social issues like that are very difficult to plan for on paper. The best way to tackle them is to try each of the multitude of incentives and disincentives which are available, and see which of them produce the best results with the least difficulties.

It would be presumptuous to offer advice to other countries (although we must reiterate the obvious truth that it only exacerbates the long-term problem to give food aid to populations which cannot support themselves and are expanding rapidly), but even in our own country, I doubt that OPT could do more than point at the obvious, such as that *unbalanced migration must not be allowed to interfere with efforts to reduce population*. Otherwise OPT could do little more than make suggestions which may or may not turn out to be effective when put into practice. Not that that really matters, because what we do know is that many countries in the European Union have total fertility rates well below replacement, so that if politicians could only be persuaded not to interfere with that downward trend, except by taking the absolutely necessary step of controlling migration, the European Union would be moving along the right path. The other fact that is almost too obvious to be worth stating is that not all countries, or groups of countries, will be wise enough to act with foresight, but that should not dissuade some from doing so.

Needless to say, the above argument will not immediately satisfy everyone, so let us turn to consider an Objection, and then make a Response.

Objection. While all the above arguments are valid, there is another matter which is at least as pressing. Due to the UK's already excessive population, the problem is as serious in the UK as in the USA, but perhaps it is more evident there, so let us look at that situation first. The influx of migrants from Latin America into the USA, and their high fertility there, has accounted for 70% of the population growth since 1970. If continued, the population will grow from 302 million in 2007 to over 450 million by 2050. What makes the USA a particularly stark example is that there is a certain Professor Jose Angel Gutierrez of Texas University, founder of the La Raza Unida Party in 1995, who could not be more open about what he hopes this will lead to. He urges followers to 'reconquer' America for a "Mestizo race" (Spanish plus earlier colonists from Siberia) which historically owned the land for forty thousand years.

There is no similar claim by anyone in the United Kingdom, but due to the power of exponential growth, the same thing would happen here over time, if we too fail to stem the tide of immigrants. Surely we in OPT should be emphasizing this danger.

Response. You are right that something needs to be done, but politicians and economists are far from convinced that population is a problem. Indeed they become worried as soon as they see a declining population. If an argument about the problem you point out is made without agreement between the two parties that population is a problem that must be dealt with, then the discussion is all about ethics and matters of judgement. Some people would say that it does not matter if America is populated by Mexicans or the UK by Indians. There are no facts by which such arguments can be conducted without agreement about the objective. Thus it is imperative to have firmly established agreement about the extent of population reduction that is necessary. I think you will agree that the six points that I put forward earlier are not yet generally accepted either by the media, politicians or economists. Thus it seems to me that it is essential for OPT to focus on matters which can be dealt with by rational analysis. Once the need to reduce population substantially is agreed, then we could participate in debate about what to do about it, but I doubt that our contributions would carry more weight than that of others. In fact what to do is a matter of common sense combined with experiment to see whether it is achieving the desired result, once the objective of a reduced population has been agreed.

What OPT can do is to continue to try to educate people about the power of exponential growth and of exponential decline. For example, if the UK could collectively achieve a rate of decline in population of 0.9% per year, then in 100 years it would have reduced its size from 60 million to $60 \times 0.991^{100} = \underline{\underline{24}}$ million. It might be possible to support a population of that size in modest comfort, one hundred years from now. But if, on the other hand, there were to be a mere 20% of the population which is expanding at say 1.2% per year, as is happening in the world in general, then that 12 million would expand to $12 \times 1.012^{100} = \underline{\underline{40}}$ million. If we suppose that the rest of the population, 48 million, still manages to achieve the same previously assumed 0.9% a year decline, and thus reduces its size to $48 \times 0.991^{100} = \underline{\underline{19}}$ million. The overall result would be a population of 59 million, which would certainly be impossible to support in the UK in 100 years time.

FOOD, ENERGY, AND SOCIETY (3rd edition), Part 1

by David Pimentel and Marcia H. Pimentel, compiled by Andrew Ferguson

One of the many things about which David Willey and I agreed was that, between them, Clive Ponting's *Green History of the World* and David and Marcia Pimentel's *Food, Energy, and Society*[1] cover almost everything that needs to be said about the fundamental proposition that OPT has always advocated, namely that the European population, the UK population and world population need to be very much smaller.

The first edition of *Food, Energy, and Society* came out in 1979. In 2008, the 3rd edition was published. It is certainly not going to be possible to convey all the subjects that are covered in its 380 pages, but I feel sure that a few gems from it will be appreciated. After making just one introductory note, namely that 1 kcal = 4186 joules, let me start right off with one of those gems, taken from the Preface. No quotation marks are used, as from now on I will let the authors speak for themselves, except for a few square bracket interjections.

xvii Large number of humans throughout the world are facing hunger and malnutrition because of political struggles and the overwhelming increase in population. The World Health Organization reports there are 3.7 billion who are malnourished. This is the largest number ever in history, and signals a serious food problem now and certainly for the future. Since 1984, food production, especially cereal grain production, has been declining per capita because of growing numbers of people, shortages of energy in agricultural crop production (e.g. fertilizers), and shortages of fresh water. …

At a time when more cropland is needed, valued fertile soil is being lost because of erosion that is 10–30 times faster than sustainability. With this environmental impact, crop yields decline, or more fertilizers and pesticides (fossil energy dependent) are used. Obviously on a per capita basis, cropland resources are declining and now are less than one-half of what is needed for a diverse diet for the world population.

Energy and Power

12.6 The survival of humans in their ecosystem depends upon the efficiency of green plants as energy converters. Plants convert sunlight into food energy for themselves and other organisms. The total foundation of life rests on plants' unique capacity to change radiated solar energy into stored chemical energy that is biologically useful for humans and other animals. …

In agricultural eco-systems, an estimated 15 million kcal of solar energy (net production) is fixed per ha per crop season. Even so, this amounts to only about 0.1% of the total solar energy reaching each hectare during the year and equals about 3500 kg/ha of dry biomass...

Under optimal conditions, during sunny days in midsummer and when crops are nearing maturity, crops such as corn and sugarcane capture as much as 5% of the sunlight energy reaching them. However, the harvested plant material is only about 0.1% because over much of the year, including winter, there is no plant growth.

[1] Pimentel, D, Pimentel, M. 2008. *Food, Energy, and Society*. Third edition. Boca Raton, Fl; London; New York: CRC Press. ISBN 978-1-4200-4667-0. CRC Press website http://www.crcpress.com

Manipulating Ecosystems for Agriculture

38.9 Neither humans, their crops, nor their livestock can exist independently from species in the natural ecosystem. A relatively small number of species — about 15 major crops and 8 major livestock types — are agriculturally produced in the world. By comparison, an estimated 750,000 species of wild plants, animals and microbes exist in the United States alone. A majority of these wild species are necessary for maintenance of the wild life system. At present, no one knows how many of the 750,000 species in the U.S. ecosystem can be reduced or eliminated before human life is jeopardized. Therefore, the existing biological diversity should be preserved and treasured. Environmental degradation caused by chemical pollutants, construction, deforestation, and other factors should be prevented.

43.8 The relationship of energy expenditure and standard of living also can be clarified by comparing production of corn by labor-intensive and energy-intensive systems. In Mexico, for instance, about 1140 h of human labor are required to produce 1 ha of corn by hand. In the United States, under an energy-intensive system, only 10 h of labor are expended per hectare. In the midwestern United States, one farmer can manage up to 200 ha of corn with the help of large fossil fuel inputs and mechanized equipment. The same farmer producing corn by hand could manage 1.5 ha at most.

Hunter-Gatherers and Early Agriculture

45.2 Before the development of agriculture and formal crop culture, wild plants and animals in the natural ecosystem were the only food for humans. How much wild plant and animal biomass is available for food, and how much land do hunter-gatherers need to meet their food needs? …

Based on the preceding calculations, a family of five would require an estimated 200 ha of habitat from which to gather animal and plant food. This estimate is based on an ideal ecosystem, one containing those wild plants and animals that are most suitable for human consumption. Researchers report that, in fact, modern-day hunter-gatherers need much more than 40 ha per person. For instance, Clark and Haswell (1970) estimate that at least 150 ha of favorable habitat per person is needed to secure an adequate food supply. In a moderately favorable habitat, these scientists estimate that 250 ha per person would be required. These estimates are four to six times greater than in the model presented earlier.

In marginal environments, such as the cold northwestern Canadian region, each person needs about 14,000 ha to harvest 912,500 kcal of food energy per year [i.e. 2500 kcal/day].

50.9 If hunters and gatherers have to work an average of 2.2 days/week to obtain food, that leaves approximately 4.8 days for other activities. These include gathering firewood, moving, constructing shelters and clothing, caring for children, and enjoying leisure time. Observations indicate that Bushmen value their leisure and enjoy dancing, visiting other camps, and engaging in other social activities.

52.4 Early plots were planted and harvested for about 2 years, then abandoned because production declined as nutrients in the soil became depleted and other problems (such as pests outbreaks) developed. Interestingly, this “cut/burn,” or “swidden,” type of agriculture is still practiced today in many parts of the world. Swidden agriculture demands that farmed land lie fallow for 10 to 20 years before it can be cleared again and farmed. During the long fallow period, the soil gradually accumulates the nutrients needed for successful crop production.

* * * * *

SO WHAT CAN WE DO ABOUT IT NOW?

by Andrew R.B. Ferguson

Knowledge about the damage that humans are doing to global systems is gradually becoming more widespread. For instance, it is *fairly* widely known that oceans are warming and acidifying, that species are becoming extinct a hundred times faster than anything that shows up in the fossil records, that water tables are being drawn down in many vital places, that per capita grain supplies have been dropping since 1984,[1] that more than 800 million people are going hungry, and more than 2000 million are suffering from malnutrition, with large numbers lacking adequate fuel supplies.

Such facts, and many like them, are *fairly* widely known, but no more than that, for the media consider that anything else should take priority as "news;" especially sports and the affairs of anyone who belongs to that miscellaneous group known as celebrities. This results in so great a barrier to doing anything significant about the problem, that any slow down in these trends is likely to be only marginal until hard realities impact upon people's everyday lives. Those hard realities are most likely to arrive — quite soon — when oil and natural gas production is falling so far short of demand that rationing has to be introduced to prevent industries from closing down or people dying of cold. At that time, it will become apparent even to those who have not bothered to address the matter previously, that it has been the availability of fossil fuels which has made it possible to support the excessive human population that we now have. These exigencies are likely to arouse an interest in global affairs that is unknown today, and a question that will seem pressing to everyone will be, "So what can we do about it now?"

That question, I find, is the one that is often asked once someone has been overwhelmed by the evidence of the damage being done by overpopulation, and with a mode of expression that indicates that nothing can be done, so the subject is better forgotten! But as time passes it will become evident that the question has to be addressed.

Since the time when civilizations lived without fossil fuels, there have been technical advances in knowledge about gathering the incoming energy from the sun. Whether those technical advances can be put to use without the benefit of fossil fuels remains to be determined. It is hard to know, for instance, whether wind turbines and their associated grid structure, and the back-up they require to maintain a constant supply, could be both built and maintained without fossil fuels. Similar doubt must hang over all the other uncontrollables, such as wave and tidal flow machines, and photovoltaic panels.

What humans do have some control over is their numbers. Yet that question, "What can we do about it now?" is usually made with the implication that what we could do about population is likely to be insignificant with respect to the nature and extent of the problem. The simple aim of this essay is to show that, irrespective of its probability of being acted upon, effective action is possible.

The following sixteen countries all have a Total Fertility Rate (TFR) of 1.3: Georgia, Singapore, Japan, Lithuania, Germany, Czech Republic, Hungary, Moldova, Poland, Romania, Russia, Slovakia, Ukraine, Andorra, Greece, and Slovenia. A TFR of 1.3 means that on average each woman gives birth to 1.3 children. With a world average TFR of 2.7, there is small likelihood of many countries getting down to 1.3 any time soon. For instance, China has been trying to implement a one-child policy for several decades, but now, in 2007, its TFR is 1.6. Nevertheless it is somewhat instructive to see what would happen if the whole world could get to the stage of achieving a TFR of 1.3. Starting from the world population spread (often called a pyramid) that exists today, a TFR of 1.3 would achieve the pattern shown in Figure 1: 100 years later, the population would be half whatever it might be at the start. Although fossil fuels will certainly be scarce in a hundred years from now, they will still not be totally exhausted, and it should be possible to keep alive the approximate 4 billion that would result, a hundred years hence, from a policy of attaining a TFR of 1.3 with all possible speed.

Thus really useful action would be possible on a world scale *except for political realities*. There is little chance of every country in the world seeing the urgency of taking appropriate action. What is more useful to consider is whether civilization might be preserved in some places where the starting position is better because there is already a TFR within striking distance of 1.3, and where the wisdom of the people and their leaders is sufficient to look a century ahead.

The United Kingdom — one of the most densely populated nations on Earth — provides a good example. It has a TFR of 1.8, so decreasing to 1.3 would only take a little political encouragement. Moreover because it has enjoyed a lower TFR for some time, its population pyramid is more or less cylindrical (i.e. parallel sided, with the same number in each age group). In fact so close to cylindrical that the graphs between cylindrical and actual can only just be distinguished, so for the sake of standardization let us look at Figure 2, which assumes a perfectly cylindrical population spread. After 100 years, population would have decreased to 37% of its starting value. Starting from 65 million, that would achieve a reduction to 24 million, which is fairly close to what OPT believes might be a sustainable population for the UK. In other words, a recovery from a disastrous situation might still be possible for one of the most densely populated countries on Earth.

Without looking at the exact population spread of the USA, but instead again assuming the cylindrical assumption of Figure 2, it can be seen that the same is true of that nation. The present TFR is 2.1. Even if the USA delays so long in getting its house in order that its population rises to 400 million before a TFR of 1.3 is established, then, if the other vital factor of ensuring balanced net migration is attended to, in only 75 years its population could be halved, to 200 million (Figure 2). 200 million is a population that could most likely be sustained — despite the intemperate climate — without the benefit of fossil fuels.

There is no need to look at every country in detail. The spreadsheet which does the calculations is very simple and requires only eight variables to be set. The important thing is the will to take action sufficiently early. No civilization in history has had the foresight to take action early enough to save itself, but then no prior civilization has had the current degree of understanding of the factors that control our destiny nor the means of communication available to us. For those nations which are prepared to put the powers of communication to better use than to inform people about sport, and the affairs of celebrities, the potential for the salvation of a significant sample of civilization is at hand.

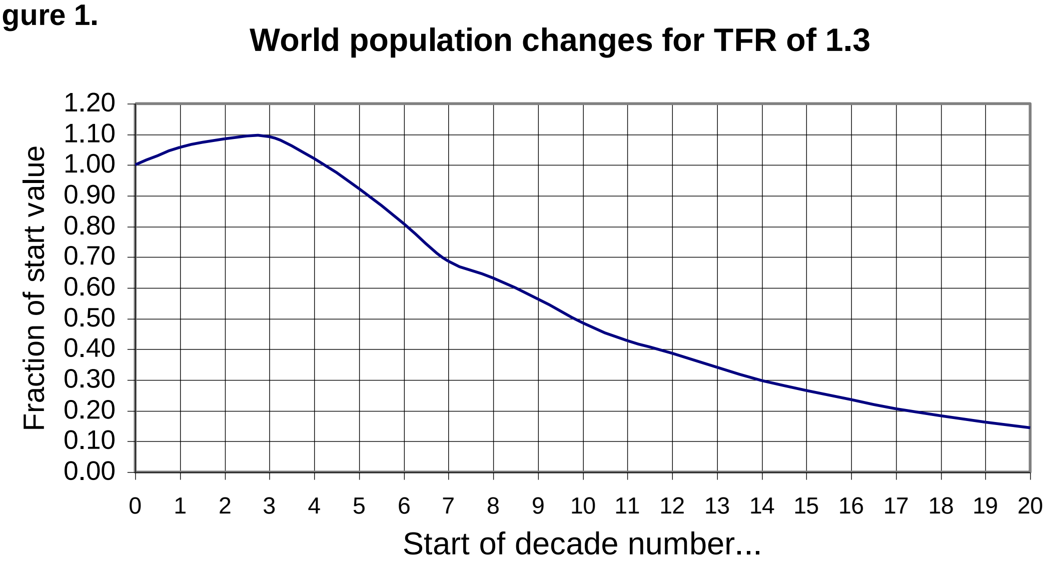
The United Kingdom and the United States are salutary examples of nations which *could* still recover, but for political reasons the likelihood of them doing so is slight. Both governments set up commissions of enquiry many decades previously, and both commissions made eminently sensible recommendations about population, but their recommendations were totally ignored by the politicians. There is currently no hint of a suggestion that wisdom and foresight have descended upon the politicians, economists and the media, all of whom worship at the shrine of perpetual growth. Beside the sixteen nations mentioned previously as having a TFR of 1.3, three other nations might serve to preserve civilization. They are Norway, Sweden and Finland, for they have TFRs of 1.9, 1.9 and 1.8 respectively, and also enjoy biocapacities per person that are about 4 times, 5 times, and 7 times the world average of 1.78, whereas the United Kingdom is 0.9 time the world average. {2}

Notes

1. The book *Food, Energy, and Society*, Third Edition, by David Pimentel and Marcia H. Pimentel, 2008, CRC Press, Boca Raton, Florida, www.crcpress.com, gives not only this relevant fact about when per capita grain supplies started to decline, but a myriad of other well referenced facts relevant to this paragraph.

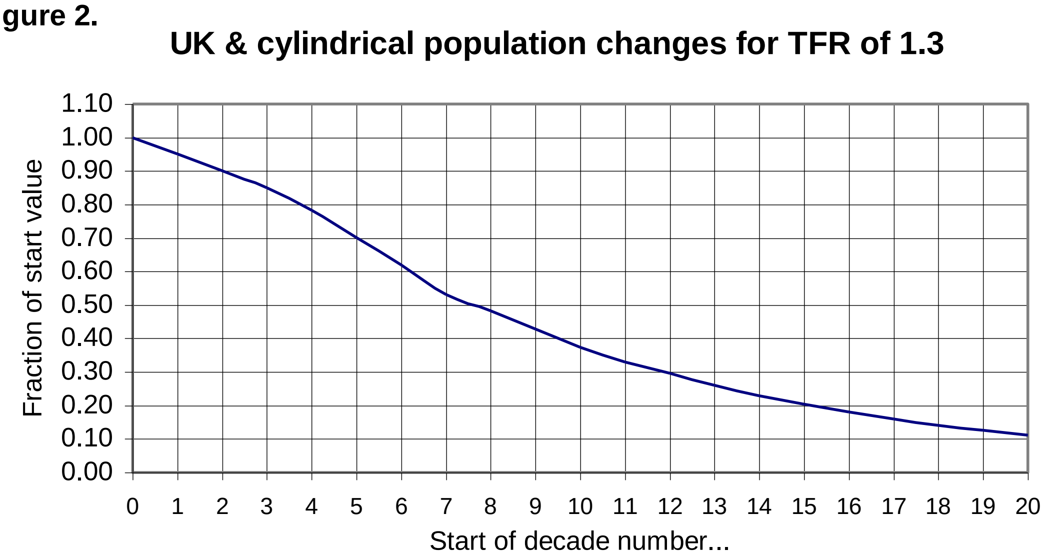
2. The biocapacity figures are taken from the 2002 edition of the *Living Planet Report 2002*, by the World-Wide Fund for Nature International, UNEP World Conservation Monitoring Centre, Redefining Progress, Center for Sustainability Studies. Ed. J. Loh. Ecological Footprints led by M. Wackernagel. WWF, Gland, Switzerland. (36 pp.).

Figure 1.



e.g. decade 0 covers years 1 to 9. Decade 1, years 10 to 19.

Figure 2.



e.g. decade 0 covers years 1 to 9. Decade 1, years 10 to 19.

POPULATION REDUCTION AND AGE STRUCTURE

by Brian McGavin

To achieve and then maintain a TFR of 1.3 until a sustainable level of population has been reached, as suggested in the previous article, would result in having relatively more older people in society, so further investigation is required about the alarm that exists in some countries concerning the costs of an ageing population. This article sets out reasons why there is far less cause to fear this prospect than is often suggested. But first we should take a look at some of the many assertions that the prospect is a cause for concern.

In March 2007, the International Monetary Fund claimed that the most developed countries face explosive debt in age-related spending, calculating that the potential gap in UK public finances caused by rising healthcare costs will be 4.8 per cent of gross domestic product — £58 billion at 2006 prices.

In 2007 the influential Davos World Economic Forum ran a seminar on *The Price of Becoming Old*. It said that OECD countries are discovering how expensive ageing can be, claiming that countries like Italy and Germany will have to spend between 25 per cent and 30 per cent of their GDP on pensions and healthcare by 2030.

Some governments are so worried that they are now giving (at the expense of taxpayers) parents extra financial incentives to have more children, and calling for more immigration to support the older generation.

The United Nations Population Division reported in its 2005 summary of population policies that, alongside HIV/AIDS, the issues of greatest concern to many countries were those related to lower fertility and population ageing. Three quarters of Governments in developed countries and 42 per cent of developing countries expressed major concern. In Latin America and the Caribbean, around two-thirds of the countries now consider population ageing to be more of a concern than population growth being too high.

So much for the concerns. Next we must enquire how soundly based is this belief in the need to counter population ageing? In a report to the British Government in late 2006, economist and chair of the UK Pensions Commission, Sir Adair Turner, showed that Britain spent about 6.2 per cent of its GDP on state pensions and stated that, "If we keep our state pension as generous as today, but still with the retirement age of 65, that economic burden will rise to 8.5 per cent by 2050." Turner continues:

> Projections show that just to maintain the ratio of 15–64 year-olds at their current level would need the UK population to rise from 59 million in 2005 to 136 million by 2050. The European Union's population of 372 million would need to rise to 1,228 million in the same period, in an ever-increasing spiral.
>
> It is also important to understand that this negative effect of low fertility is offset by some powerful economic benefits of smaller families and low population growth. Smaller families mean less expenditure on rearing children and on education: increased public expenditure on pensions partially offset by less on public education. And smaller families mean that people on average inherit more housing capital, simply because if you are one of two children, you will on average inherit one half of your parent's house, whereas if you are one of three, you inherit a third. And that inherited housing capital is then available at least in part to fund consumption in retirement.

He adds that, "The potential importance of housing equity is very large." It is indeed. The value of housing assets in the UK, even after mortgage debt, is considerably larger than all pension funds combined.

OPT makes the further point that, "In looking at the economic costs of supporting an ageing population, it is necessary to balance these against the economic costs of population growth. These include the billions of pounds in higher taxes needed to build sewage facilities, housing and other infrastructure to accommodate ever-rising population numbers." It points out that in the UK, 43% of young people go into higher education and can therefore be dependants until well into their 20s, and continues: "Financial assistance is given *down* the generations (not up) on average until the age of 75. With less population growth, productive work can be aimed at improving quality of life, instead of building ever more infrastructure and housing."

British economist Phil Mullan, in *The Imaginary Time Bomb,* believes the preoccupation with an ageing population that will place intolerable strains on health and pensions plans has less to do with demographic fact and more to do with an agenda to cut back the welfare state.

Mullan states that "the dependency ratio" is a crude device for assessing generational burdens, and goes on to say:

> The implication that everyone between 16 and 64 works is an absurdity …The unemployed, students, early retirees and housewives do not generate tax revenue. The increased number and proportion of the elderly needs to be set against the decline of health expenditure on children as a result of the decline in the birth rate.
>
> Countries with much older age structures have out-performed those with younger ones, and business cycles and growth rates are demonstrably unconnected with the age profile of a nation. … Wealth generation has nothing to do with either the average age of the population nor with demographic ratios. By contrast, deployment of, or failure to deploy, new technologies massively affect output per worker.

In short, Mullan states that, "No one has come up with a compelling financial case why ageing is so burdensome." And affirms that, "There is no demographic time bomb. The anxiety about ageing that has become endemic in the 1990s is misplaced. It is entirely exaggerated. Sometimes commentators with particular obsessions or vested interests have manipulated it."

A raft of expenditure supporting young people is being ignored — child allowances, tax credits and the cost of years of education. Crime and the criminal justice system is another area where young people are disproportionately over represented. Around 42 per cent of all first time offences in the UK were committed by 18 to 20 year-old men, according to the UK Social Exclusion Unit in 2005. Young people aged 15 to 24 make up 47 per cent of the total 186 million people out of work world-wide in 2003, while only making up a quarter of the working age population, according to the International Labour Organisation. The problem is even more pronounced in developing countries.

A brief examination of the UK Government's 2007-2008 total expenditure on services shows around £76 billion could quickly be linked to support costs for young people, with around £71.5 billion attributable to supporting the over-65s.

Health is another area where older people are considered a burden. In a study of health costs, Professor Raymond Tallis of Manchester University found the total days of in-patient care for people who died at 90 was only about double that of people who died at 45. Eighty per cent of men over 85 are living at home, successfully looking after their personal care unaided. Even half the 95-plus age group were still fully independent and only one in five people ever need institutional elderly care. The prevalence of disabilities at older age is also falling, he says. In the 1980s it was predicted the number of strokes would rise by 28 per cent in 20 years, but by 2004 numbers fell by 29 per cent. UK Department of Health data found it was only the 85-plus group where average health costs rose significantly. To sum up: population reduction is essential and may not be painful at all.

RENEWABLE ENERGY CANNOT SUSTAIN A CONSUMER SOCIETY

A Review Essay by Andrew Ferguson

The sixth of OPT's *Six Inconvenient Truths* (OPTJ 7/1 p. 18) starts thus: "The belief of economists and the commercial world in *ever continuing* growth is impossible." This is one theme of Ted Trainer's recent book, *Renewable Energy Cannot Sustain a Consumer Society*. So OPT recognizes this economic problem as being fundamentally important. If we have not been continuously banging the drum on that theme it has been because we have been fully occupied in banging a different drum on another matter of key importance, namely the delusion that our present population can be supported on renewable energy. In so doing, we have been dealing with "tech-fix optimists," and we would subscribe to Ted Trainer's description of them (p. 8), that they are "to be found in plague proportions in the renewable energy field." Tackling this subject is the major theme of his new book.

For the most part, his study is greatly to be admired. He has covered an amazing breath of literature on the subject, and tackled subjects that I have fought shy of, like trying to assess how much wind capacity would actually be available at various places. It is good to see that while he attempts such assessments, he also recognizes that the primary problem is not availability, but rather the difficulty of using uncontrollable power sources to produce a supply appropriate to satisfying consumer demand. He correctly arrives at the conclusion that although a wind penetration of 20% (wind supplying 20% of electrical energy) may be achievable in some places, it is likely to be considerably lower than that in many places.

His treatment of photovoltaics (PV) is also commendable, although I would have liked him to bring out the fundamental problem of PV, namely its low capacity factor. He does bring out the subject in an indirect way, but the matter is simple and compelling, so let us dwell on it briefly. The relationship is this:

Capacity factor = k x (insolation on a horizontal plane in W/m^2 / 1000)

where k is a constant. As far as it has been possible to assess, the value of k is 0.70 (OPTJ 4/2 p. 29). Essentially the constant takes into account those factors *other than illumination being less than 1000 W/m^2* which result in degradation of PV performance, e.g., dust, deterioration, and the sun impinging on the module at oblique angles. The 1000 represents the 1000 watts per square metre illumination used in the laboratory test.

Thus, for the example, in the USA where average insolation is about 200 W/m^2 (it might be slightly lower, closer to 190 W/m^2) the capacity factor of PV modules is 0.70 x (200 / 1000) = 14%. This capacity factor figure, which of course is lower even that the dismal wind output that Denmark and Germany get from their systems, immediately shows the nature of the problem when using PV. In fact the problem is even worse than the comparison with wind suggests. How much an uncontrollable power source can contribute to an electrical system is determined by the ratio 'capacity factor / peak infeed (from the uncontrollable source). In the E.On Netz wind system in Germany, where the wind turbines are spread over 800 km, peak infeed is about 80% of capacity, thus if we suppose that the capacity factor is 18% (which is higher than the 16% achieved in one particular year) then on that basis alone wind can satisfy 18 / 80 = 23% of the energy requirement. It is necessary to say "on that basis alone" because there are two remaining questions, (a) can the controllables deal with the large variations of input from the wind system? (b) if one tries to get 23% of the electrical supply from wind, then at an 18% capacity factor with a peak infeed factor of 80%, the actual peak will be (0.23 / 0.18) x 0.80 = 102% of mean demand. Can the system manage that?

If the wind is trying to feed in 102% of mean demand when the demand is actually at a low level — low demand is about 60% of mean demand — then there is a problem about what to do with all the extra output from the wind.

But to go back to why PV is worse than wind, let us suppose that we choose a very sunny place where the capacity factor is 18% (just about possible). When there is sunshine over a wide area the peak infeed is 100% (actually with PV it can be over 100%). Then what the PV system can contribute to the electrical system is 18 / 100 = 18%, i.e. less than wind's theoretical 23%. However PV does have one advantage. It can just about be guaranteed that the peaks in PV output will not coincide with low consumer demand, so the electricity output is less likely to be a problem even with a substantial penetration.

That usefulness is somewhat abated if another uncontrollable is being fed into the system, say tidal flow, wave, or wind, for then peak infeed from those uncontrollables would, on occasions, exacerbate a peak infeed problem arising from PV; that is another point to which Ted Trainer does not give much emphasis, namely that the problems arising from introducing uncontrollables into an electrical system are additive.

These are minor criticisms of a certainly broad and generally excellent treatment of the uncontrollables, including a comprehensive study of the inadequacy of all current methods of storing electricity.

Trainer does a good job of setting out the problems of the low power density of energy from biomass, particularly when the biomass is turned into liquid form, which he correctly points out represents only about a third of the energy in the biomass itself. He is also correct in pointing out that the inputs required to produce the biomass and effect the conversion to a liquid form amount to about the same quantity of energy as the output achieved in liquid form. He does not go on to mention something that I think gets insufficient attention. Even in a renewable energy world, it would be possible to produce liquid energy from biomass, but, and this is the point not mentioned, the additional inputs which are needed to effect the conversion, and which currently come from fossil fuels, would have to be produced from renewable sources, e.g. short-rotation woody crops. But this would have a further significant effect on the power density measured in terms of a useful output. For one thing, more of the liquid output would have to be used for the purpose of harvesting, transporting and preparing the woody crops, reducing the useful output. For another the area needed to grow the woody crops would have to be added to the area needed to grow the biomass to make the liquid fuel. Both these factors would further lower the already low power density of producing liquid fuels.

But all these points are minor criticisms. Trainer is excellent in showing why the so called "Hydrogen Economy" is a fantasy, and why nuclear energy is not the answer. In other words, his study of renewable energy is comprehensive, and in addition to this he writes a couple of chapters to bang the drum that OPT has not been banging as much as it should, namely to show that the whole idea of continuing a capitalist growth economy is going to become more impossible in a renewable energy world even than it is today.

It should be mentioned that Ted Trainer does not attempt to assess the number of people that could live the Simpler Life he advocates when it is based entirely on renewable energy. But then perhaps he regards that as the province of the Optimum Population Trust. The figure is 2 billion on the basis of living off renewable energy, and, based on present per capita carbon dioxide emissions, 2 billion is equally applicable to the present time.

References

OPTJ 4/2. 2004. *Optimum Population Trust Journal*, Vol. 4, No 2, October 2004. Manchester (U.K.): Optimum Population Trust. 32 pp. Archived on the web at www.optimumpopulation.org/opt.journal.html

OPTJ 7/1. 2007. *Optimum Population Trust Journal*, Vol. 7, No 1, April 2007. Manchester (U.K.): Optimum Population Trust. 32 pp. . Archived on the web at www.optimumpopulation.org/opt.journal.html

Trainer, T. 2007. *Renewable Energy Cannot Sustain a Consumer Society*. Dordrecht, the Netherlands: Springer. 197 pp. ISBN-13: 978-1-4020-5548-5 (HB); ISBN-13: 978-1-4020-5549-2 (e-book).