population matters

for a sustainable future

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Page

`The banking world became very siloed in part because it all looked so complicated and geeky and boring', says Gillian Tett, one of the few journalists who was willing to work through banking's complexity to see what was going on. But there are lots of issues like that — like global warming and poverty and science — and these are really going to affect our lives! We can't afford to delegate knowledge of these things to experts because that's how those siloes get built. And not just in businesses but in our lives, in our society.

Margaret Hefferman in *Wilful Blindness*, p322, 2011

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INTRODUCTION

In the previous issue of this journal it was noted that : "Lester Brown is particularly good on irrigation. He points out that half the world's population live in countries where water tables are falling, and worldwide 70% of water is used for irrigation." Without doubt water is a vital subject. Chapter 14 of David and Marcia Pimentel's book *Food, Energy, and Society* deals with it comprehensively, including the all important matter — particularly when looking ahead several decades — of the energy required to use it.

Some chapters in the book *Food, Energy, and Society* are written by David Pimentel in conjunction with the students that he is leading through a course. Chapter 14 has the names of nine students to accompany that of David Pimentel. Each time I go back to this book to choose the material for another instalment, I am astonished at its breadth and depth. I hope that the chosen excerpts convey some idea of what this chapter covers, but it is necessary to be selective, and thus leave out much interesting detail. The selections are made with an eye to conveying the extent to which it is reasonable to see a decline in agricultural output, as energy becomes a scarce commodity.

One thing that should be made clear about these ongoing instalments of this book by the Pimentels is that in the book all the facts are very well referenced, but I do not include these references in the excerpts. It also occurs to me that within the instalments I have not given a reference to the 2008 book itself. In these days of computers, it is not difficult to locate it from the title, *Food, Energy, and Society*, but in case it is helpful here is the ISBN number : 978-1-4200-4667-0

This article often refers to "1000 L". To help anyone having difficulty in picturing the volume occupied by 1000 litres, it is equal to a cubic metre.

Pages 7-10 comprise a short paper titled *Food Energy and Lifestyle Energy*. The essential theme of this is similar to *Food, Energy, and Society*, insofar as it attempts to bring out the importance of the energy we need other than food energy. Based on an idea from a Canadian scientist, J.R. (Jack) Vallentyne (1926 – 2007), the presentation attempts to convey in a simple form the difficulty of gathering that energy from renewable sources. A key point from the Abstract of this piece is, "It is further noted that it is unlikely that the whole world will wake up to this problem in time, thus every nation should be taking upon itself the challenge of matching its population to the number that can be *sustained* in the absence of the temporary advantages of fossil fuels."

On pp. 11–17 is a nine page review of Margaret Hefferman's book *Wilful Blindness*. In the OPT Journal it has frequently been mentioned that the problem of overpopulation is as much a problem of human willingness to think clearly about the problem, as an inability to grasp obvious facts, such as the fact mentioned in Chapter 14 of *Food, Energy, and Society* that 3 billion people are malnourished and that we are adding people to the planet at a rate of nearly a quarter of a million each day. The two books previously referenced in this regard have been the 1841 book by Charles Mackay, *Extraordinary Popular Delusions and the Madness of Crowds*, and the 1947 book by Rupert Crawshay Williams, *The Comforts of Unreason: A Study of the Motives behind Irrational Thought*. Margaret Hefferman's book, published in 2011, has a very similar focus on the weakness of human minds, and updates these previous efforts. She provides examples of 'wilful blindness' culled from the recent financial exuberance, which led the industry to issuing financial instruments that were opaque to everyone, while faith in markets continued even as the danger of that faith was made manifest.

On the title page of this journal there is a quotation from *Wilful Blindness* which applies in large measure to renewable energy. People always prefer to hear and read, and indeed believe, that there will be a smooth transition from fossil fuels to renewable energy. As Hefferman says, "We can't afford to delegate knowledge of these things to experts". As with high finance, the issues are complicated and effort is required to master them, but to do so is important, for through many issues of this journal we have seen that most of the experts in the field are wishful thinkers, just as most economists were until the financial problems became impossible to deny. In many respects most of them continue to be.

The next piece, on pp 18–20, *Total Fertility Rates (TFRs) and Avoiding Catastrophe*, illustrates how hugely dependent a population trajectory is on the Total Fertility Rate (TFR). It also shows that an *average* TFR for a nation can be highly misleading, as a small proportion of the population, with a somewhat higher TFR, can quickly undo the effort of the rest of the population whose TFR is below the replacement level of 2.1.

Pages 21–22, follow on similar lines with *Consequences of High Fertility rates within Populations*. The opening paragraph makes manifest the importance of TFRs : "The variation in Total Fertility Rates throughout the world is substantial. For instance, taking Africa as a whole, the average is 4.7, whereas in the European Union it is 1.6, and in the USA 2.0. Within Africa there is wide variation; it is often well above the average — 5.2 in Sub-Saharan Africa; 6.4 in Uganda, and 7.0 in Mauritania." This piece looks in some detail at the United Kingdom, showing that it illustrates in practice what is also shown in theory, that a small group with a higher TFR can have a disproportion effect. The article also emphasises the fact that many nations will not take the difficult steps that are necessary to control their population. The corollary of that is that no nation can bank on drawing food and energy resources from other places in the world, and each nation needs to ensure that it can sustain its own population. The fact that almost no nation recognizes the truth of that is an example of Margaret Hefferman's *Wilful Blindness*.

I have Walter Youngquist to thank for the final piece on pages 23–28, as he sent me the book *Power Hungry* by Robert Bryce. Bryce is excellent on exposing the weak foundations of a belief in a transition to living off renewable energy, but his 'solutions' — natural gas and nuclear energy — are relatively short term palliatives.

All internet addresses given in previous OPT Journals as pointers to the availability of these journals on the internet are now superseded. The webpage to access all OPT Journals, current ones and previous ones, is now: http://tinyurl.com/optj2

When David Willey founded the Optimum Population Trust (OPT) in 1991, he set out the two main aims of the OPT as:

- To promote and co-ordinate research into criteria that will allow the optimum population of a region to be determined.
- To increase awareness, particularly among those who influence opinion, of the results of this research.

The OPT Journal, which started publication in 2001, has remained focused on these aims. However OPT has spread its aims to cover wider matters; to reflect this, the 'working name' of the organization has been changed to *Population Matters*. The OPT Journal retains its name, in part because it has now become a familiar name amongst its readers, and in part because it remains the best description of what the journal is about. The website of Population Matters is to be found at www.populationmatters.org

FOOD, ENERGY, AND SOCIETY (3rd edition), Part 8

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

Chapter 14. Water resources: agricultural and environmental issues.

183.3 Per capita food supplies (cereal grains) have been decreasing for nearly 20 years (declined 17%), in part because of shortages of fresh water, cropland, and the concurrent increase in human numbers. Shortages in food supplies have in part contributed to more than 3 billion malnourished people in the world. Two of the most serious malnutrition problems include iron deficiency affecting 2 billion people and protein/calorie deficiencies affecting nearly 800 million people. The iron deficiency and protein/calorie deficiency each result in about 0.8 million deaths each year. Humans obtain all their nutrients from crops and livestock and these nutrient sources require water, land, and energy for production. …

Population growth, accompanied by increased water use, will not only severely reduce water availability per person, but will stress all biodiversity in the entire global ecosystem.

… Overall, water shortages severely reduce biodiversity in both aquatic and terrestrial ecosystems, while water pollution facilitates the spread of serious human diseases and diminishes water quality.

AVAILABILITY OF WATER

184.8 Regions that receive low rainfall (less that 500 mm/year) experience serious water shortages and inadequate crop yields. For example, 9 of the 14 Middle Eastern countries (including Egypt, Jordan, Israel, Syria, Iraq, Iran, and Saudi Arabia) have insufficient fresh water.

Substantial withdrawals from lakes, rivers, groundwater, and reservoirs that are used to meet the needs of individuals, cities, farms, and industries already stresses the availability of water in some parts of the United States. When managing water resources, the total agricultural, societal, and environmental system must be considered. Legislation is sometimes required to ensure a fair allocation of water. For example, laws determine the amount of water that must be left in the Pecos river in New Mexico to ensure sufficient water flows into Texas.

185.6 At present, world groundwater aquifers provide approximately 23% of all water used throughout the world. Irrigation for U.S. agriculture relies heavily upon groundwater, with 65% of irrigation water being pumped from aquifers.

Population growth, increased irrigated agriculture, and other water uses are mining groundwater resources. Specifically, the uncontrolled rate of water withdrawal from aquifers is significantly faster than the natural rate of recharge, causing water tables to fall by more than 30 m in some U.S. regions from 1950 to 1990. The overdraft of global groundwater is estimated to be 200 x 10^9 m^3 or nearly twice the average recharge rate.

186.0 Similar problems exist throughout the world. For example, in the agriculturally productive Chenaran Plain in northeastern Iran, the water table has been declining by 2.8 m/year since the late 1990s. Withdrawal in Guanajuato, Mexico, has caused the water table to fall by as much as 3.3 m/year.

STORED WATER RESOURCES

186.2 In the United States, many dams were built during the early twentieth century in arid regions in an effort to increase the available quantities of water. Although the era of constructing large dams and associated conveyance systems to meet water demand has slowed down in the United States, dam construction continues in many developing countries worldwide.

Given that the expected life of a dam is 50 years, 85% of U.S. dams will be more than 50 years old by 2020. Prospects for the construction of new dams in the United States do not appear encouraging. Over time, the capacity of all dams is reduced as silt accumulates behind them. Estimates are that 1% of the storage capacity of the world's dams is lost due to silt each year.

AGRICULTURE AND WATER

187.5 The water required by food and forage crops ranges from 600 to 3000 L of water per kilogram (dry) of crop yield. For instance, a hectare of U.S. corn, with a yield of approximately 9000 kg/ha, transpires about 6 million L/ha of water during the growing season, while an additional 1–2.5 million L/ha of soil moisture evaporate into the atmosphere. This means that about 800 mm (8 million L/ha) of rainfall are required during the growing season for corn production. Even with 800–1000 mm of annual rainfall in the U.S. Corn-Belt region, corn frequently suffers from insufficient water during the critical summer growing period.

A hectare of high-yielding rice requires approximately 11 million L/ha of water for an average yield of 7 t/ha (metric tons per hectare).

IRRIGATED CROPS AND LAND USE

188.3 World agriculture consumes approximately 70% of freshwater withdrawn per year. Approximately 17% of the world's cropland is irrigated but produces 40% of the world's food. Worldwide, the amount of irrigated land is slowly expanding, even though salinization, water logging, and siltation continue to decrease its productivity. Despite a small annual increase in total irrigated areas, the per capita irrigated area has been declining since 1990, due to rapid population growth. Specifically, global irrigation per capita has declined nearly 10% during the past decade, while in the United States irrigated land per capita has remained constant at about 0.08 ha.

188.8 Overall the amount of energy consumed in irrigated crop production is substantially greater than that expended for rainfed crops. For example, irrigated wheat requires the expenditure of three times more energy than rainfed wheat. Specifically, about 4.2 million kcal/ha/year is the required energy input for rainfed wheat, while irrigated wheat requires 14.3 million kcal/ha/year to apply an average of 5.5 million L of water.

Delivering the 10 million L of irrigation water needed by a hectare of irrigated corn from surface water sources requires the expenditure of about 880 kWh/ha of fossil fuel. In contrast, when irrigation water must be pumped from a depth of 100 m, the energy cost increases up to 28,500 kWh/ha, or more than 32 times the cost of surface water.

189.2 The large quantities of energy required to pump irrigation water are significant considerations both from the standpoint of energy and water resource management. For example, approximately 8 million kcal of fossil energy are expended for machinery, fuel, fertilizers, pesticides, and partial (15%) irrigation, to produce 1 ha of rainfed U.S. corn. In contrast, if the corn crop were fully irrigated, the total energy inputs would rise to nearly 25 million kcal/ha (2500 L of oil equivalents). [An editorial interjection is appropriate here, as the following has some bearing on the next article in this issue. The calorific value of a corn (maize) crop, yielding 8.6 t/ha, is 31 million kcal, so the energy inputs required for a fully irrigated corn crop would be 25 / 31 = 80% of the food value of the crop. The energy we use for growing crops is only a small part of all the energy we use, but it is significant.]

189.6 Drip irrigation delivers water to individual plants by plastic tubes and uses from 30% to 50% less water than surface irrigation. In addition to conserving water, drip irrigation reduces the problems of salinization and water logging. Although drip systems achieve up to 95% water efficiency, they are expensive, maybe energy intensive, and require clean water to prevent the clogging of the fine delivery tubes.

SOIL SALINIZATION AND WATER LOGGING IN IRRIGATION

189.7 With rainfed crops, salinization is not a problem because the salts are naturally flushed away. But when irrigation water is applied to crops and returns to the atmosphere via plant transpiration and evaporation, dissolved salts concentrate in the soil where they inhibit plant growth. The practice of applying about 1 million L of irrigation water per hectare each year results in approximately 5 t/ha of salts being added to the soil. The salt deposits can be flushed away with added fresh water but at a significant cost. Worldwide, approximately half of all existing irrigated soils are adversely affected by salinization. Each year the amount of world agricultural land destroyed by salinized soil is estimated to be 10 million ha.

190.0 Water logging is another problem associated with irrigation. Over time, seepage from irrigation canals and irrigated fields cause water to accumulate in the upper soil levels. …For example, in India, water logging adversely affects 8.9 million ha of cropland and results in the loss of as much as 2 million tons of grain every year.

COSTS OF WATER TREATMENT

193.5 Purifying and reducing the number of polluting microbes in water, as measured by the BOD (Biological Oxygen Demand) is energy costly. Removing 1 kg of BOD requires 1 kWh. … Excluding only the energy for pumping sewage, the cost and amount of energy required to process 1000 L of sewage in a technologically advanced wastewater treatment plant is about 65¢ and requires about 0.44 kWh of energy. …

Dependence on the oceans for fresh water has major problems. When brackish water is desalinized, the energy costs are high, ranging from 25¢ to 60¢ / 1000 L, while seawater desalinization ranges from 75¢ to $3 / 1000 L. In addition, transporting large volumes of desalinized water adds to the cost.

FOOD ENERGY AND LIFESTYLE ENERGY

by Andrew R.B. Ferguson and Eric Rimmer

Abstract

The looming problem of food shortages has been covered in impressive detail by Lester R. Brown, but the slightly more distant, though probably more grave, problem of energy shortage receives less attention. Moreover it is difficult to relate the two problems. A method of doing so is illustrated here, leading to the conclusion that it would be at least a wise precaution to reduce populations to the size that could be sustained in the absence of a breakthrough in the technology of converting solar energy to types of energy that can be stored and used on demand by humans. It is further noted that it is unlikely that the whole world will wake up to this problem in time, thus every nation should be taking upon itself the challenge of matching its population to the number that can be *sustained* in the absence of the temporary advantages of fossil fuels.

In a recent book (2004), *Outgrowing the Earth: The food security challenge in an age of falling water tables and rising temperatures*, Lester Brown paints a detailed picture of the looming difficulties of supplying the world with sufficient food. On page 17 he summarizes the problem thus:

> It is difficult to overestimate the challenge that the world faces over the next half-century. Not only are there a projected 3 billion more people to feed, but there are also an estimated 5 billion people who want to diversify their diets by moving up the food chain, eating more grain-intensive livestock products. On the supply side, the world's farmers must contend with traditional challenges, such as soil erosion and the loss of cropland to nonfarm uses. But now also with newer trends such as falling water tables, diversion of irrigation water to cities, and rising temperatures.

In this book, as always, Lester Brown shows an impressive ability to analyse agricultural problems. However, he pays scant attention to the longer term problem — and probably a significantly graver one — of energy shortage when fossil fuels become scarce, and the consequent further demand on fertile land to supply that energy. To those unfamiliar with energy units, it is hard to convey the magnitude of the energy problem, and set it within the context of the problem of food insecurity. A helpful way of joining the two ideas is suggested by the concept of a Canadian scientist, J.R. (Jack) Vallentyne (1926 – 2007). He developed the instructive idea of expressing energy units in terms of *the average energy consumed as food per person, per year* (based on a modest daily intake of 2333 kilocalories). We may refer to this amount of energy as a *Food Energy (FE)* unit. It is equivalent to burning continuously a 113 watt bulb (0.15 horsepower) throughout a year.

What makes this unit informative is that we are familiar with the fact that fertile land with adequate rainfall is required to provide each of us with food; moreover with the present size of population, it is evident that suitable land is becoming scarce. Additional to Brown's warnings, we may note that according to the World Health Organization 3.7 billion people are suffering from malnutrition.{1} And there are many books, for example A *New Green History of the World: the Environment and the Collapse of Great Civilizations* (Ponting, 2007), showing that humans have, in many places, put overwhelming demands on natural resources, even to the point of causing mass extinctions, as outlined in *The Sixth Extinction: Biodiversity and its Survival*, by Leakey and Lewin, 1996. Clearly further stress on natural resources should be avoided.

Prior to the discovery of fossil fuels, with some limited exceptions such as whale oil, humans acquired the energy needed for heating and cooking by burning biomass, which of course depended on having additional fertile land on which to grow such fuel. The development of modern civilization, including such things as general education, hygiene and health care, has only been possible because of a substantial increase in the energy that each of us uses directly and indirectly to maintain our 'lifestyle'. The figures that Vallentyne gives show that 'lifestyle' energy for each person, *in the part of the world he surveyed in 1990*, was, on average, 24 FE units (Table 1), i.e. 24 times the energy needed to feed us. Partly because the population in the undeveloped world has grown more rapidly than in the developed world, *average* 'lifestyle' world energy use is now slightly lower than that (about 20 FE units), but the population has increased from 5.3 billion in 1990 to 7 billion in 2011, and total energy use has increased and is increasing.

A fairly well established figure for the minimum *average* fuel use in order to maintain a modest, but civilized lifestyle is 18 FE units (equal to a steady 2 kilowatts or 2.7 horsepower).{2} This can also be thought of as 40% of the present per capita energy use in the United Kingdom; and 40% is approximately true based on European consumption.

Looking ahead to the time when fossil fuels are scarce, these 18 FE units per person illustrate the enormity of the problems the human race is likely to face. If all that energy could be gathered from such things as wind turbines and solar collectors, there would be little problem, but there is only a small chance that that will be possible, as it requires finding a satisfactory way of storing electricity. Moreover the whole idea of building such solar energy collection devices on the necessary huge scale is in doubt, mainly because of the large amount of materials, particularly rare metals, that would be needed.{3}

Leaving the second complex point aside, let us deal with the first. The intermittent nature of solar electricity collection is such that it seems likely that only a third of the total energy could be gathered that way.{4} The remaining two-thirds, amounting to 12 Food Energy units per person, would need to be from a controllable source — presently that substantially means biomass.

It is already evident that the present population is trying to take too much from the soil, mainly just to provide food and clothes. History provides a continuous picture of humans exhausting soils by over cropping (Montgomery, 2008). The unreality of taking 12 times more energy from the soil, so as to provide ourselves with the energy to maintain a civilized (though modest) lifestyle, is apparent because the 'lifestyle' demand from 7 billion people would be equivalent to the *Food Energy* demand of 84 billion people.

Lester Brown mentions the important point that an estimated 5 billion people want to move up the food chain. But probably more important, in the longer term, is that the same number of people want to move *up* the 'lifestyle energy ladder', and many developed countries will have great difficulty moving *down* to the 'modest' amount of 18 FE units.

It is evident that in the absence of access to fossil fuels, only a much smaller population could be supported in a modest but civilized lifestyle; that is unless there is some unforeseen breakthrough in capturing and storing solar energy. On average, plants only capture one part in a thousand of solar energy.{5} That is why, although the amount of solar energy is huge, there is only a small amount of the current flow of solar energy that we can make use of. We surely should not be risking the lives of billions on the chance that a technological breakthrough will occur. A further thought is that it is very unlikely that the whole world will wake up to the problem in time. Every nation should be thinking about its own energy situation once fossil fuels run out. The United Kingdom is in a particularly perilous position. At present, with the population already exceeding the size that can be fed and clothed, the population is expanding, so prospects are getting worse.

Table 1 'Lifestyle' energy use in 1990 expressed in terms of Food Energy (FE) units

Rank	Country	FE units per nation millions	Population millions	So FE units per person
1	Qatar	73.0	0.368	198.5
2	UAE	259.6	2	163.4
3	Bahrain	66.3	0.516	128.5
4	Canada	3,132.1	27	118.1
5	Norway	460.0	4	109.2
6	United States	22,754.2	249	91.3
7	Iceland	21.0	0.253	83.2
8	Sweden	663.7	8	78.6
9	Kuwait	139.1	2	68.2
10	Finland	326.9	5	65.7
11	German Dem Rep	1,048.1	16	64.5
12	Australia	1,069.7	17	63.4
13	U.S.S.R.	16,536.5	289	57.3
14	Belgium	549.4	10	55.8
15	Netherlands	832.8	15	55.7
16	New Zealand	188.3	3	55.5
17	Czechoslovakia	835.1	16	53.3
18	Saudi Arabia	739.2	14	52.3
19	Germany, Fed Rep	3,053.9	61	49.8
20	Trinidad & Tobago	60.2	1	47.0
21	Switzerland	303.4	7	45.9
22	United Kingdom	2,541.3	57	44.4
23	France	2,475.7	56	44.1
24	Bulgaria	387.4	9	43.0
25	Austria	323.0	8	42.6
26	Singapore	111.4	3	40.9
27	Denmark	209.3	5	40.7
28	Romania	907.6	23	39.0
29	Japan	4,666.8	123	37.8
30	Poland	1,448.5	38	37.7
31	Hungary	375.7	11	35.6
32	Italy	1,945.8	57	34.1
33	Libya	151.3	5	33.3
34	Ireland	113.1	4	30.4
35	Oman	42.4	2	28.2
36	Venezuela	534.8	20	27.1
37	Greece	269.3	10	26.8
38	Korea, DPR	577.0	22	26.5
39	Israel	113.6	5	24.7
40	Spain	956.2	39	24.4
52	Mexico	1,355.5	89	15.3
55	Brazil	2,105.2	150	14.0
79	China	8,201.2	1,139	7.2
109	India	3,071.1	853	3.6
121	Haiti	18.9	7	2.9
142	Bangladesh	150.3	116	1.3
143	Cape Verde	0.3	0.37	0.8
144	Comoros	0.2	0.55	0.4
	Totals and hence average	**86,165**	**3,597**	**24.0**

Endnotes

1. Pimentel, D. and Pimentel, M. 2008, p.xvii.
2. Vaclav Smil has shown that for all countries with a good education system and adequate health care 2 kW per person is required. Some support is given to this on page 188 of Moriarty and Honnery's. *Rise and Fall of the Carbon Civilisation* (2010). The energy requirement figure must vary widely depending on climate. Howard Hayden (2004, p.20), shows that prior to 1890, when railways and electricity increased the demand for power, average power use in the USA was 3.7 kW per person (equal to 3.7 / 0.113 = 33 FE units per year).
3. http://thebulletin.org/web-edition/columnists/dawn-stover/the-myth-of-renewable-energy Bulletin of the Atomic Scientists. *The myth of renewable energy* by Dawn Stover , 22 November 2011.
4. The limit to the amount of uncontrollable power that can be incorporated into an electrical grid has been a recurring theme in the OPT Journal. One particularly relevant article is on pages 13-20 of OPTJ 10/2, October 2010, under the title *Controllable Power Limits Total Power*.
5. Pimentel, D. and Pimentel, M. 2008, p.20. Pimentel gives a table which shows that annual net primary production in U.S. agricultural ecosystems is about 5 tons/ha. He goes on to mention that corn (maize) grown under favourable conditions can produce 9 tons/ha of grain plus an additional 9 tons of stover. This represents about 0.5% — 5 parts per thousand — of the solar energy falling on the area. He mentions that this is a relatively high rate of conversion for crops and natural vegetation. "Most crops have about 0.1% level of conversion."

   While intensive cultivation can improve on 0.1% that usually involves significant inputs, and a quite rapid loss of soil. Corn and sugarcane can be used to produce ethanol, but these are two of the most soil damaging crops (Pimentel, 1993). Also everything that is required to maintain a civilized lifestyle cannot be accomplished by burning biomass directly. A lot has to be converted into liquid fuels. This involves losses in conversion, and the output is reduced by the inputs necessary to effect the conversion. Also relevant is that corn stover should be left on the ground to maintain soil fertility. Taking these factors into account, an average 0.1% level of conversion is not far out.

   It may be noted, too, that the average natural forest regeneration is 3 tons/ha, which is equal to about 2 kW/ha, or one part in a thousand of the average 2000 kW/ha insolation in the USA.

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WILFUL BLINDNESS by Margaret Hefferman

A review essay by Andrew Ferguson

A letter in *New Scientist*, 19 February 2011, by Peter Stockdale (Enderby, BC, Canada) serves as a reminder that foresight about population matters is not all that difficult:

> Reading your editorial about futurology reminded me of a course I took in 1970 while I was a postdoctoral fellow at the University of California. The theme was "California in 2000 AD," and speakers gave presentations on topics as diverse as hydrology, farming, urban planning, forestry and economics.
>
> I have been amazed at how accurate their forecasts were. The prediction of a world population for the year 2000 of 6 billion, increasing at a billion per decade, proved close to the mark. More worrying was the prediction of a population crash when we reached 9 billion in the middle of this century.
>
> Despite the changes in climate and loss of biodiversity that we are seeing, our political leaders seem unable to bring about the necessary changes in how we treat our planet. Watch the world news on TV and you will see the future: it is Haiti.

Haiti does provide a current example of humans overwhelming the natural resources of their country, but historically Easter Island is a better one, as it had no likelihood of anyone from outside coming to its rescue, which of course applies to the world as a whole.

While some predictions are difficult, it has not been hard to make the prediction that a growing human population in a world where many people are still seeking to acquire sufficient resources to keep comfortably clothed, warm, healthy — especially through good sanitation — and educated, will, during the 21st century, exhaust the Earth's resources. In the first edition of their book *Food, Energy, and Society* (1979), David and Marcia Pimentel were warning of the need for a human population of about two billion if everyone is to enjoy a *modest* version (half the current energy use) of lifestyles in the USA.

In 1965, I made a determined effort to persuade those of my fellow pilots with whom I came into extended contact that the world already had as many people as it could sustain comfortably. When unsuccessful there, I would go on to argue that the time could not be far away before it had more people than it could sustain. I did not manage to persuade a single one of them of the first proposition, and only a few would somewhat unwillingly concede that there was some truth in the second one. My lack of success may have been in part due to a lack of persuasive power, but I think it is fair to see it mainly as an example of 'wilful blindness'.

If that is true, it is apparent that all who care about the human race need to find ways of overcoming wilful blindness. Previous issues of the OPT Journal have drawn attention to *Extraordinary Popular Delusions and the Madness of Crowds* by Charles Mackay (1861), *The Comforts of Unreason: A Study of the Motives behind Irrational Thought* by Rupert Crawshay-Williams (1947), and *When Prophecy Fails* by Festinger et al (1956). The last of these shows that when people wish to believe something, and have adjusted their lives in accordance with that belief, and are surrounded by others in a similar situation, then there is no level of disproof sufficiently compelling to get more than a few of them to change their minds. Indeed, in such circumstances disproof usually serves to strengthen belief!

Festinger's work is one of many related studies outlined in a recent book with the title, *Wilful Blindness*, by Margaret Hefferman (2011). The book updates what is said in the aforementioned books. Because the subject is of paramount importance to anyone wishing to mitigate the catastrophe that the human race is heading towards, we would do well to heed what it says, so I will start by outlining a couple of the examples given by Hefferman.

Echoing the insight of Crawshay-Williams, Hefferman describes how the human mind subconsciously tries to reconcile two desires, the first being to believe that we are being rational, and the second to hold on to the comfortable world view that each of us establish in order to make us feel good about ourselves and the world in general. The following are just two of the many examples she gives.

One question which troubled Dr Alice Stewart was why there had been, in recent decades, such a notable increase in childhood leukaemia. With a grant of a £1000, she came up with a clear answer : the chance of a child dying when the mother had had an obstetric x-ray was three times as much as that of a mother who had not had one. As Hefferman says, “The recognition that x-raying pregnant mothers so dramatically increased the chances of childhood cancer was the kind of finding epidemiologists dream of : a hard problem with good data pointing to a clear solution.”

Alice Stewart published her results in 1956, in the *Lancet*, in an article, ‘Preliminary communication : malignant diseases in childhood and diagnostic irradiation *in utero*’. She followed this up with an extended study covering 80% of all childhood cancer deaths in England between 1953 and 1955, with her report being published in the *British Medical Journal* in 1958. It concluded definitively that the foetus exposed to an x-ray was twice as likely to develop cancer within the next ten years as compared to a foetus that had not been exposed. In the early 1960s, a radiation study examined 6 million x-ray subjects. It confirmed Stewart’s results. Despite all this evidence, it was not until 1980 that major American medical organizations finally recommended that the practice of using x-rays during pregnancy be abandoned. The place that held out longest was England.

As Hefferman points out, the conclusion of these studies was something that doctors had a strong inclination not to hear, because it meant that over the past several decades they had been harming many of their patients. Moreover the advent of x-rays had much increased the effectiveness and hence authority of doctors, and finally they were unwilling to abandon their long-held belief that there was a ‘safe’ level of irradiation.

Our second example is Alan Greenspan, who took over as chairman of the Federal Reserve Bank in 1987. As explained by one of his long-standing critics, Frank Partnoy (himself a very successful financial operator until he gave it up in disgust), “Greenspan believed in the core of his soul that markets would self-correct and that financial models would forecast risk effectively.”

Greenspan had plenty of opportunity to see the writing on the wall. In 1994, when he raised interest rates from 3% to 3.25% and a few months later to 3.75%, that increase was sufficient to cause the collapse of several large financial organizations. Hefferman tells us that “Property and casualty insurers lost more than they had paid out on Hurricane Andrew : hedge funds, banks, securities firms and the life insurance industry lost billions.”

Hefferman tells us, “Gillian Tett, *Financial Times* journalist, compared Greenspan’s blind faith to that existing in the medieval church,” and Hefferman goes on to say that, “Each one of these debacles reinforced the same lesson : derivatives were a ‘dark market’. No one knew what went on in these deals and, because there was no statutory requirement to report anything, even the parties to the deals often did not know what they had. Had there been any reporting requirements, at least those with most at stake might have gained some insight into their own exposure.”

Hefferman relates that in 1988 Muriel Siebert testified before the subcommittee on Telecommunications and Finance, in the wake of the 1987 market crash, to the effect that the major problem with the market was derivatives.

Greenspan’s wilful blindness to the problems was such as to withstand even Brooksley Born, who was appointed to head up the Commodity Futures Trading Commission in 1996, and given the task of regulating the $27 trillion derivatives market. After the string of catastrophes in 1994, she was one of the few eager to impose some oversight. But Greenspan resisted the changes that she saw as essential, and the free market continued to grow, leading her to resign from the Commission. After the collapse of the hedge fund Long-term Capital Management, she said, “Long-term Capital Management was exactly what I have been worried about. No regulators knew it was on the verge of collapse. Why? Because we didn’t have any information about the market.”

Even after the financial collapse in 2008, Greenspan was unable to recognize that he had been *totally* wrong, conceding only that his theory was ‘flawed’ in some details.

In 2001, Enron, the sixth largest corporation in America, went bust. Many such collapses might be interpreted as further illustrations of wilful blindness, but in most of them, those involved may have appreciated the risks they were laying on the shoulders of others, but greed led them to continue anyway. Greed is unlikely to have been operative with the doctors, and certainly was not with Greenspan, which makes the above convincing examples of wilful blindness rather than deceit. There are other examples from the world of economics, perhaps the most egregious being the belief of the great majority of economists that a growing economy is necessary, while ignoring the fact that if even half the present world population were to live in European lifestyles, it would hopelessly overload demand on resources. There are motivations to overlook problems when, for instance, it might lead to the loss of a well paid job, but even without such personal motivation, there is no doubt that wilful blindness is widespread amongst economists.

Perhaps it will only be possible to demonstrate wilful blindness entirely convincingly when it can be shown how the brain blocks messages that it does not want to hear. Hefferman records the first steps in investigations using fMRI scanners, but interpretation of the results is equivocal. The evidence needs to be more compelling before brain scans can serve as a useful measure of this disastrous human failing.

A brain scanner is not required to see that wilful blindness with respect to population is rampant. There are many motives for people avoiding recognition of the problem of overpopulation. Here is just one of the many covered in the book by Crawshay-Williams, with its subtitle, *A Study of the Motives behind Irrational Thought*. The motives are in essence desires, conscious or subconscious, which we seek to satisfy. One such desire is to conform with popular opinion, about this Crawshay-Williams writes :

> This desire leads to more irrationality than almost any other desire, … [It is] in many ways … fundamentally unreasonable in that it impels us to adopt opinions without evidence — to regard them as ‘self-evident’ merely because they are prevalent among the community in which we live. This does not necessarily mean that the opinions themselves are wrong; it only means that to accept them without evidence is irrational.
>
> The existence of this desire (it would perhaps be better called impulse, since it is largely unconscious) in individuals of a gregarious species called man is now generally accepted among sociologists, though its potency is usually much underestimated among laymen. Like the desire to feel good, it springs partly from the herd instinct; the herd would not have survived the course of evolution unless there were a powerful impulse in its individuals which made them conform in matters of general welfare. …
>
> The nearest we can get to cure or prevention of the trouble is awareness; our only chance of minimizing the effects of our impulses is to recognize them and as far as possible to discount them.

These points were clear enough in 1944 when Crawshay-Williams wrote the book, because in 1919 Wilfred Trotter had written on the same subject in his book *Instincts of the Herd in Peace and War* (Crawshay-Williams quotes him extensively).

Since 1944 psychologists have succeeded in quantifying the problem more accurately, showing that we have essentially two personalities, a social personality, and an individual one appearing when there is no need to interact with other members of the herd. Hefferman gives a description of a famous experiment carried out in 1968 by Bibb Latane and John Darley. They placed either one, two, or three people in a room, having given them the task of filling in a questionnaire. They arranged that the room should slowly start to fill with smoke. They found that with only one person in the room, within two minutes the person would start to look for the source of the smoke, and go and get help. With two people in the room, and repeating the experiment many times, they found only one out of ten people would report the smoke. The rest stayed put, filling in the questionnaire even though they were coughing and rubbing their eyes ! With three people in the room, it transpired that only one in twenty-four people reported the smoke within the first four minutes. It is not hard to imagine what was going on in the minds of people who ignored the smoke. It was probably on the lines of : 'Well no one else is complaining so why should I?'. On the other hand, their task was not to endure smoke, but to fill in a questionnaire, so there was no taboo in drawing to the attention of the others to the fact that there appeared to be smoke entering the room and something should be done about it.

The situation with regard to overpopulation is starkly different. Most people are proud of their children and, if they have them, grandchildren, and do not easily contemplate that it might have been better were they not to have brought so many people into the world. Throughout history, the bearing of children has been something to celebrate, and the taboos surrounding any different view are vastly greater than raising worries about smoke in the room. It is little wonder that the desire to conform is a major barrier to getting people to think clearly about population. The 'wilful blindness' extends to not wanting to know, or at least dwell on, the many ways in which humans are having a detrimental effect on the other creatures living on land or in the seas, and instead adopting the comfortable view that things can go on 'forever' as they have in recent decades.

The psychologist who puts a finger most accurately on the way in which wilful blindness is apparent in organizations whose concern should include population is Albert Bandura, whom Hefferman introduces to the reader as, "The grand old man of psychology : its most cited living author." She writes about his views as follows.

> So persuasive (and pervasive) has the economic argument in favour of population growth become, says Bandura, that all of the major NGOs have had to stand aside from it. Fear of alienating donors, criticism from the progressive left and disparagement by conservative vested interests claiming that overpopulation is a 'myth' served as further incentives to cast off the rising global population as a factor in environmental degradation. Population growth vanished from the agendas of mainstream environmental organizations that previously regarded escalating numbers as a major environmental threat. Greenpeace announced that population 'is not an issue for us'. Friends of the Earth declared that 'it is unhelpful to enter into a debate about numbers'. The fear of losing money disabled those very organizations best placed to understand the ultimate consequences of thinking only about money.
>
> What money does, Bandura argues, is allow us to disengage from the moral and social effects of our decisions. As long as we can frame everything as an economic argument, we don't have to confront the social or moral consequences of our decisions. That economics has become such a dominant, if not the prevalent, mindset for evaluating social and political choices has been one of the defining characteristics of our age.

What Bandura says is what the Optimum Population Trust has found to be true countless times. Even when someone takes the time to understand an important and well presented issue, as for instance humans having severely damaged their environment as set out in Clive Ponting's *A Green History of the World*, the lessons soon get forgotten in favour of more pleasant thoughts. Quoting Frank Partnoy, Hefferman writes:

> Certain aspects of history just tend to disappear : We hear it but don't want to hear it — so it goes away. And then we have to learn all those important lessons anew. Many of my students haven't heard of Ken Lay, or Michael Milken, or Ivar Kreuger. There are kids graduating now who know nothing about Enron.

The conclusion to draw from all this is that weaknesses inherent in the human mind are of paramount importance. It is not sufficient to show, with ever greater clarity, that while the last two centuries has seen the rise of the carbon civilization the next two centuries will see its fall, and that from the moment the decline becomes established, there will be much suffering. In addition to that task, it is also necessary to attempt to tackle the fundamental problem of the human mind having a strong tendency to follow the herd, and use wilful blindness as a means of indulging in comfortable beliefs, such as that when fossil fuels become scarce, technology will present us with a suitable alternative.

It was the curse of the mythical Cassandra to never be believed. Margaret Hefferman devotes a later chapter to giving examples of modern Cassandras who have had the satisfaction of eventually being believed, and appropriate action being taken. Such examples are not common, and there is much truth in the witty words with which Rupert Crawshay-Williams finished his book:

> EPILOGUE
>
> Whether or not I have made a reasonable case for the views expressed in this book, I leave the reader to judge, confident that — if I am right — his opinions will probably remain unchanged whatever anyone says.

Now let us look at where wilful blindness has seeded itself in the fertile field of renewable energy among renewable energy enthusiasts, e.g. within *The Centre for Alternative Technology* and in magazines like *New Scientist* and *Scientific American*, and thereby amongst media people such as television and radio interviewers. Similar to financial matters, the subject is sufficiently complicated that most people feel it has to be left to the 'experts'. The result is to allow ignorance of the following matters to flourish :

1. That the amount of fossil energy needed to produce ethanol from corn (maize) is either equal to or, in more comprehensive analyses, about fifty per cent more than the energy contained in the ethanol.
2. That even when the need for those inputs is overlooked, and only the output of ethanol is taken into account, the power density achieved as useful ethanol is pitifully low, about 1.9 kW/hectare. That is to say, a hectare (10,000 square metres) of fertile land is needed to provide energy equivalent to almost a couple of bars of an electric heater. And 1.9 kW can be put in the context of each western European currently consuming about 5 kW (120 kWh/day) of energy; yet if the whole area of the UK were divided amongst its 60 million people, each person would have only 0.4 hectares. In the U.S., energy consumed is about 11 kW/person.
3. That the electricity from wind turbines can only contribute about 20-25% of electrical supply. Ignorance about this is rife, despite the fact that it is a matter of arithmetic and

commonsense. The commonsense is that the amount of uncontrollable electricity that can fit into an electrical system depends on the *peak* output of the uncontrollable system (for wind over the whole UK close to 100% of total capacity, but about 80% over the whole of Germany) while the *average* output of wind systems was between 2003 and 2007, taking the European Union as an example, 21%, with a low of 18% for Denmark, and a high of 29% for Ireland and Greece (Smil, 2010, p138). Commonsense thus indicates something less than a 21 / 80 = 26% limit, and the same conclusion about the limits to wind penetration has been arrived at in a detailed model by Oswald (2007) and in a literature review by Lenzen (2009).

4. That the variability problems of uncontrollables is additive. For example, if the peak outputs from wind sometimes exceeds demand at noon on weekends, there is no room for any additional output at midday from photovoltaics (PV).
5. That the capacity factor (ratio of the average power to the peak power) of photovoltaics is significantly lower than for wind turbines (10% in Germany and only reaching about 20% in the best locations such as Arizona). It is rare to come across any mention of the capacity factor of PV so this widespread blindness is not surprising.
6. That making PV modules more efficient (by which is normally meant the ratio of the amount of electricity produced from a square metre to the intensity of irradiation) does not change the capacity factor (which is dependent on the amount of solar insolation at that location). Even the doyen of energy experts, Vaclav Smil, appears not to appreciate this point (Smil 2010, p151).
7. That the power density of biomass is low even without transformation to a liquid fuel. It can be put at 5 kW/ha, but that is only applicable to particularly suitable areas with good rainfall and plantations able to produce 8 tonnes of dry wood per year.
8. That handling biomass presents various problems. This is something that does not escape Vaclav Smil. He writes : "Biofuel enthusiasts envisage biorefineries using plant feedstocks that replace current crude oil refineries — but they forget that unlike the highly energy-dense oil that is produced with high power density, biomass is bulky, tricky to handle, and contains a fairly high share of water." (Smil 2010, p115).
9. That although in undeveloped countries there is still some room for further development of hydroelectricity, in developed countries there is little such scope, so to provide *controllable* electricity from renewable sources there is little except electricity from biomass for providing the 75% of electricity which remains after uncontrollables have contributed their maximum (25%).
10. That if biomass is used for producing electricity, then its already low power density of say 5 kW/ha is likely to be reduced to about 1.25 kW/ha due to unavoidable losses in the process of transformation to electricity.
11. That a country importing food and fibres (e.g. timber), like the UK, cannot make itself sustainable by using its land to produce biofuels and then importing more food and fibres (amazingly, this obvious fact is often overlooked).
12. That if a country is able to produce a lot of electricity from uncontrollables, e.g. Denmark which produces about 20-25% of its electricity demand from wind, that fact gives no indication of the achievable limits of wind penetration, *if*, like Denmark, the country can export its peaks of wind turbine output to neighbouring countries (as Denmark does with a large proportion of its wind generated electricity).

13. That putting forward arguments without quantifying them is of little use. For instance, solar enthusiasts argue that solar *thermal* overcomes the problem of intermittency of uncontrollables because they can store energy as heat. However, before such an argument has any weight, it needs to be shown that solar thermal heat storage can cope with the major problem of solar thermal, namely seasonal variation (even at latitude 35º average winter output is only about 20% of summer output, Trainer 2007, p168).
14. That the possibility of large scale storage of electricity remains highly uncertain.
15. That as the fate of a substantial part of the human race will be dependent on finding a way of replacing the energy currently available from fossil fuels, proposals regarding any very effective alternative supply need to have a very high probability of being successful, otherwise precautionary action is needed to guard against the catastrophe of being able to support only a fraction of the existing population.
16. That the exact date — within a few decades — of peak oil, peak gas, and peak coal is not of much importance, because the adjustments in population sizes, needed to deal with declining supplies of energy, will take at least a century.
17. That although it is possible that some countries may take action to match their population to their environmental capacities in the absence of fossil fuels, it is beyond the range of possibility that all countries will do so, therefore each nation needs to strive to achieve that for itself.

There are similarities between the financial crisis described by Hefferman and the coming crisis with energy supply. Gillian Tett and Frank Partnoy did their best to draw people's attention to the inevitable consequences of the current situation, but few people engaged their minds sufficiently to follow their arguments. The consequences of a similar failure with respect to energy will be more catastrophic, so it is of vital importance to overcome people's inclination to wilful blindness, and to spread the message emanating from the efforts of those who have beavered away at these complex interrelated problems.

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TOTAL FERTILITY RATES (TFRs) AND AVOIDING CATASTROPHE

by Eric Rimmer and Andrew Ferguson

Abstract: It is evident that to avoid catastrophe the world as a whole needs to achieve a low Total Fertility Rate (TFR), but it is vain to hope that all nations will act accordingly. Indeed the only example we have in history of a nation controlling the size of its population over a long period of time is the tiny island of Tikopia. It thus behoves every nation to find ways of limiting its own population so as to be sustainable. Migration can easily upset the best efforts of the indigenous population.

Demographers tend to devote their efforts to making projections about future populations as things appear to be going at present. But what is more important is to decide where we need to be going in view of the multiple changes that are likely to decrease the planet's human carrying capacity. The list of those troublesome changes is long, but it includes, water shortage (as water tables are drawn down), desertification, loss of topsoil, declining fish stocks, climate change (making all farming more difficult), increasing cost of fossil fuels making fertilizers expensive, flooding (due to rapid melting of glaciers and heavy rain), rising sea levels and subsiding coastal cities (often due to water extraction). But perhaps larger than all these will prove to be a huge decrease in the energy available to us as fossil fuels become scarce.

If these detrimental changes take substantial effect before 2100, and that is certainly on the cards, then the magnitude of the changes needed in human behaviour are apparent from Figure 1. Let us look at some figures briefly before drawing conclusions.

In 2010, the average world Total Fertility Rate (TFR) according to the World Population Data Sheet of the Population Reference Bureau was 2.5. If within ten years it could be reduced to 2.0, then by 2100 world population — having peaked in 2060 — would be about 8.8 billion. Similar ten year reduction to a TFR of 1.75 would result in a 2100 world population of 6.7 billion. A reduction to a TFR of 1.5 would result in 5.1 billion, and a ten year reduction to 1.0 would produce a world population in 2100 of about 2.4 billion.

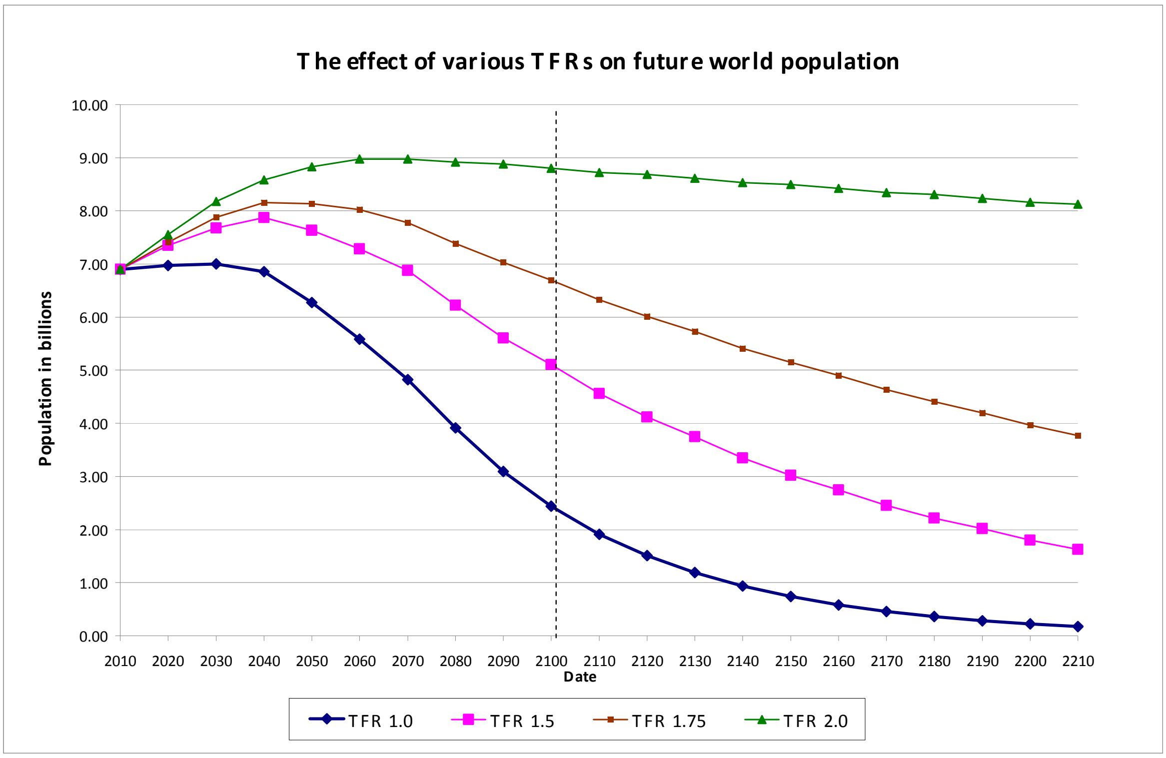
What is mainly going to determine which of those numbers is closest to the actual carrying capacity in 2100 is largely a matter of the extent to which we are capable of overcoming the multiple problems facing humanity, most particularly the ability to find substitutes for fossil fuels.

But taking an overview of the world as a whole is of little value, because even faced with the obvious facts of deteriorating environments, many nations will not take adequate steps to reduce the size of their population in time. For instance, China has taken some steps but it remains in doubt if those steps will be sufficient, especially in view of its environmental problems, such as falling water tables and the danger of large scale coastal flooding of fertile land. India still has to take action that can be shown to be effective. Japan, which is already overpopulated, has become worried at a falling population. This tendency to regard falling populations as a problem is widespread. Governments and economists seem incapable of taking a long term view. Indeed limiting population to a level that is sustainable is almost unheard of in human history. The tiny island of Tikopia may be the only example (it continued with a policy that controlled its population for a thousand years, and probably would have continued to prosper were it not for its "discovery" by the outside world).

If each nation needs individually to take steps to reduce to a sustainable level the impact of each person and the size of their populations, then the fact will have to be taken on board that for some countries migration is as great a problem as is too high a TFR. Moreover it is hard for governments to take steps to encourage their native population to a low TFR if altruistic action by their citizens to lower population — people often want more children — is being undone by unbalanced migration.

What is evident is that in order to avoid the sort of catastrophe that overtook Easter Island, nations need to consider their own carrying capacity and aim for a TFR that will get them to where they need to be. One very important factor is the likely availability of energy, which is why the OPT Journal devotes so much space to it.

Figure 1



TFR_ASMR_ER_XLS (4).xls

In positing that a whole population will keep to a specified TFR there is an obvious simplification, and hence errors, but it can still be illuminating to see what happens under such simplified assumptions, so let us take an example which will illustrate why it is so unrealistic to imagine that the human race as a whole will be able to control its population.

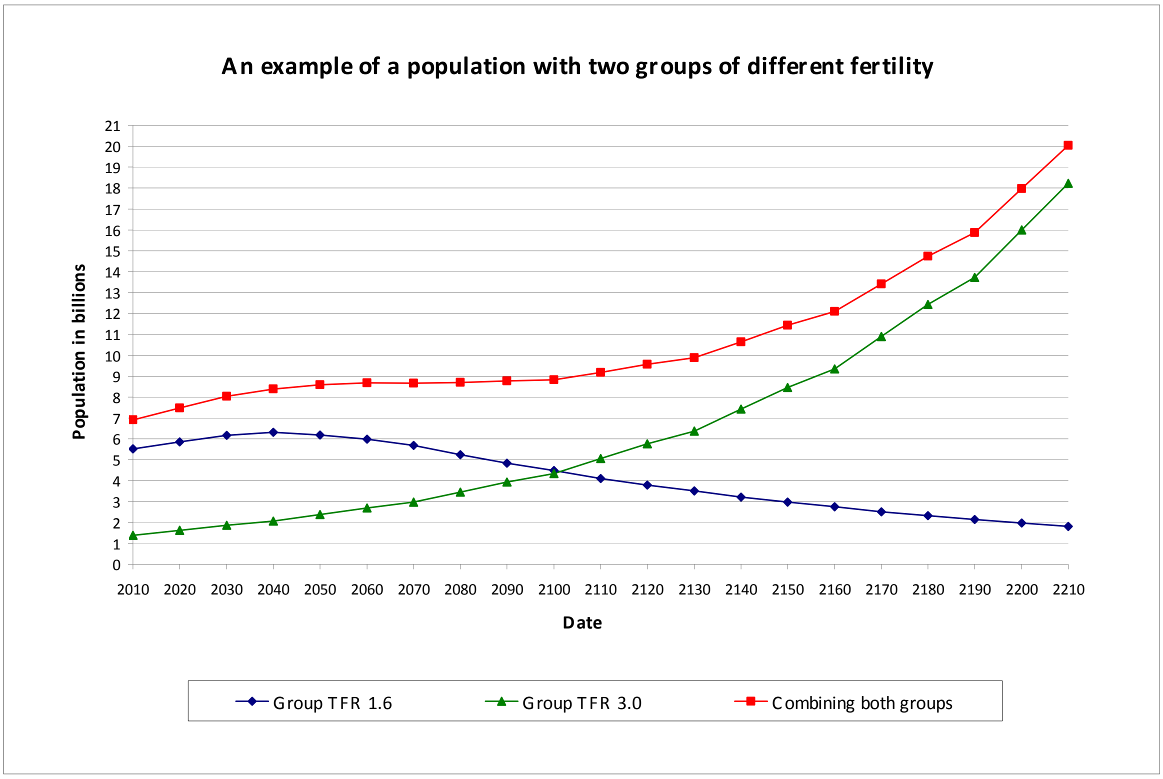
There are half a dozen countries that have managed to get their TFR down to 1.6. Now imagine that, by some miracle of wise foresight, 80% of the world's population achieves a steady TFR of 1.6. The size of that hypothetical 80% would be 5.5 billion at the start in 2010. By 2100 it would have *fallen* to 4.5 billion (Figure 2). About 15% of the present world population has a TFR of 3.0 or greater, so, as an illustrative hypothesis, 20% of the population staying at a TFR of 3.0 is not unrealistic. Starting at 1.4 billion, that group would *expand* to 4.3 billion by 2100.

Combining the populations of the two groups gives a world population of 8.8 billion by 2100. The effect of the 20% becomes more apparent with the passing years. By 2210, the 1.6 TFR group has decreased its size to 1.8 billion. But by maintaining a TFR of 3.0, the group that started as 20% of the population, would have increased its size to 18 billion, (making it constitute 91% of a combined world population of 20 billion).

A further example of the extent to which an average TFR does not give an accurate projection of future populations — if there is wide variation from that average — is from one United Nations projection. The average TFR is 2.5, and under the hypothetical concept of each woman having 2.5 children, by 2100 the world population would be about 14 billion. However the UN Constant Fertility variant, which must use the fertility of each group within the whole population, produces a population of 27 billion by 2100.

The lesson from this is clear enough, and goes to confirm the earlier assertions: it is unrealistic to assume that a sufficiently large proportion of the world will act with foresight to get world population into balance with ecological resources. The best that can be realistically hoped for is that some nations will have sufficient foresight to ensure that their population is of such a size that they can sustain themselves (climate permitting) in the way the Tikopians managed to achieve on a small island for at least a millennium.

Figure 2



TFR_ASMR_ER_AVERAGE-2_XLS (3).xls

CONSEQUENCES OF HIGH FERTILITY RATES WITHIN POPULATIONS

by Eric Rimmer and Andrew Ferguson

Abstract: Any substantial group of citizens feeling little responsibility for achieving sustainability through low birth rates can easily upset sterling efforts by the rest of the population. That is illustrated here both in theory and by recent projections for the UK from the Office of National Statistics, which point a finger at immigration.

The variation in Total Fertility Rates throughout the world is substantial. For instance, taking Africa as a whole, the average is 4.7, whereas in the European Union it is 1.6, and in the USA 2.0. Within Africa there is wide variation; it is often well above the average — 5.2 in Sub-Saharan Africa; 6.4 in Uganda, and 7.0 in Mauritania.

The most important lesson deriving from a study of Total Fertility Rates (the average number of children per woman) is that a substantial group within a population who are somewhat unrestrained in their fertility can quickly undo the 'good work' of another substantial group who are restraining their fertility. Although later the theme will be about the United Kingdom, let us look at this in the context of a world population as in Figure 1, which shows population starting at 7 billion. We then take a look at various hypotheses. We will focus on the figures for the year 2100, as people are somewhat unwilling to think further ahead — and perhaps with good reason because the future becomes more uncertain the further one progresses into it.

The lowest curve in Figure 1 shows how population would change with a change (over ten years) to women having, on average, only two children — a TFR of 2.0. Population would rise for a time due to the present age distribution; but by 2100 it would be 9 billion, dropping very slowly.

The top curve shows how population would change were every woman to have three children — a TFR of 3.0. The size of population would race away, reaching 22 billion as soon as 2100. These are theoretical concepts, because we are ignoring the constraints of water, food, and energy shortage, and all such things. But the results serve to show that the 'good work' of those women confining themselves to two children, which give a prospect for a world of 9 billion by 2100, would be massively undone were a substantial number of women to have three children: the curve below the top one shows what would happen were half the women in the population to allow themselves two children while the other half allow themselves three. By 2100, the population would be 15 billion.

Were we to look at more substantial variations, which are evident in reality as mentioned in the first paragraph, the difference would be larger, but even the ± 0.5 variation shows up as a substantial difference as early as 2100. Figure 1 shows that by then the effect of the half of the population with a TFR of 3.0 would have caused the population to increase by 6.5 billion, that is a 92% increase from the starting point of 7 billion, whereas if all had stuck to an average of 2.0 there would have been a slight drop in the population.

These proportions do not exactly hold true for the United Kingdom because the present age distribution is different from that of the world, but with the UK already overpopulated, the dangers attendant upon an increase anywhere near 93% are obvious.

The overarching lesson is that the efforts of a substantial portion of the population to constrain their fertility can be quickly overcome by a lesser restraint from the rest. An illustration of this, appertaining to the UK, was reported in The *Times* newspaper — and in the media generally — on 27th October 2011. It was stated there:

> The report, from the Office of National Statistics (ONS), said that the population was growing rapidly and was projected to rise from 62.3 million last year to reach 70 million by 2027.

As argued in the OPT Journal over many years, the *optimum* population of the UK is about 20 million, so we are already starting from a very bad place, but that 20 million puts in context the projected addition of 7.7 million.

The rate of increase implied by those figures is also alarming. A rise from 62.3 million to 70 million in 17 years indicates a rate of increase of 0.68% per year. Were that to continue to 2100, then the UK population would rise to 115 million. At least it would if the rest of the world was willing to feed us!

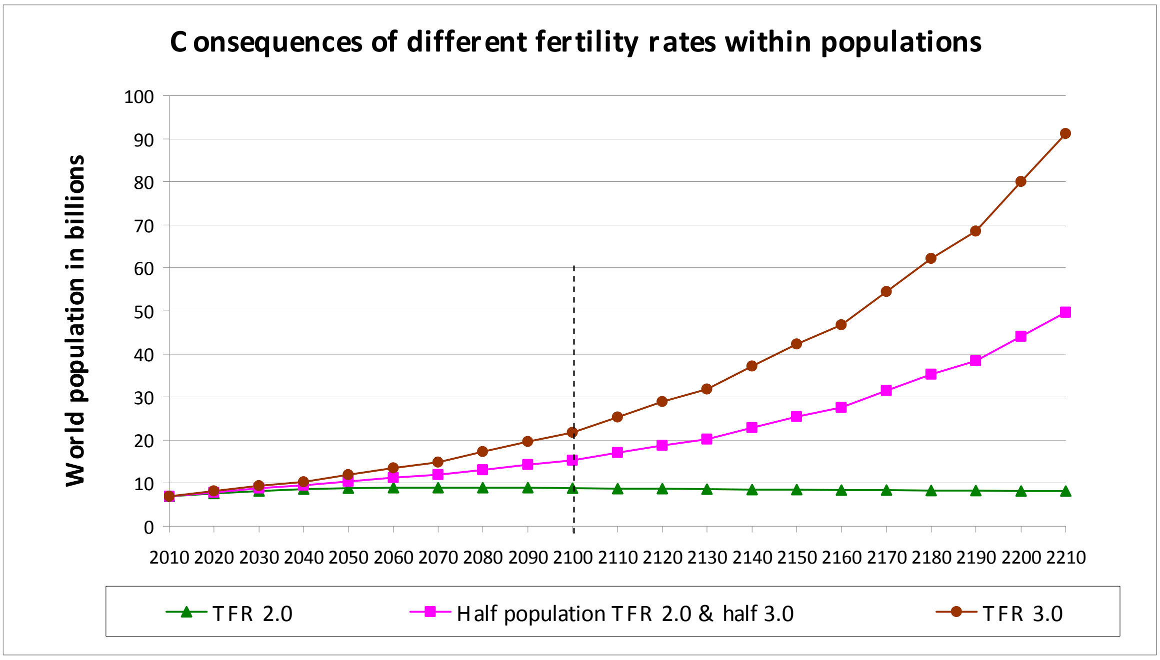
The report goes on to say:

> Two thirds of the overall increase is due to immigration, either directly through new migrants arriving or indirectly through a higher birthrate to immigrant mothers. The remaining third is because of a general increase in births and increase in longevity.
>
> The projections are based on an assumption that net migration — the difference between those arriving and those leaving — will continue at 200,000 a year inward.

200,000 a year for 17 years amounts to 3.4 million. Subtracting that from the increase of 5.1 million which is estimated to be due "either directly through new migrants arriving or indirectly through a higher birth rate to immigrant mothers" leaves 1.7 million attributable to a "higher birthrate to immigrant mothers." Our government, like others before them, have stated their intention to reduce immigration, but results so far are deeply discouraging.

The lesson of Figure 1 remains clear, namely that if our population is to be reduced to a sustainable level, not only is it necessary that the present inhabitants should attain a below replacement TFR (which is about 2.1), but that there should not be a group of citizens within society who feel no obligation to play their part in achieving sustainability.

Figure 1



TFR_ASMR_ER_AVERAGE_XLS (2).xls

POWER HUNGRY by Robert Bryce *

A review essay by Andrew Ferguson

Abstract. Almost the only *relatively* high power density (and possibly affordable) source of renewable power is wind energy. Yet Robert Bryce shows that it is dubious whether it would be advisable to supplement controllable power with wind power more than to a small extent. As with his earlier book, he does an excellent job of showing up the general ignorance of politicians and the media about these important issues. He also puts correct stress on the low power density of all controllable sources of renewable power. Bryce does not address one key question, namely the extent to which it will be possible to produce energy from renewable energy sources alone. But the information he has gathered does throw some light on that question.

Before the publication of *Power Hungry*, Robert Bryce wrote a book titled *Gusher of Lies*. It was well reviewed. Its thrust was summed up in the Wall Street Journal thus:

> It is hard to ignore Bryce's main point — the politicians and pundits are woefully uninformed about energy. When you hear a presidential candidate or a TV talking head calling for energy independence, or claiming that we can reduce carbon emissions by 60 or 70 percent, or pointing to windmills, ethanol, and solar panels as the energy future of the American economy, you can be fairly certain that they are wasting their own energy on false promises and futile schemes.

The subtitle of *Gusher of Lies* is *The Dangerous Delusions of Energy Independence*. Bryce tells us that he was stimulated to continue his work with the book *Power Hungry* by his failure to convince people that prospects for a transition to renewable energy were dim. The subtitle of *Power Hungry* is *The Myths of 'Green' Energy and the Real Fuels of the Future*. Bryce deems the 'real fuels of the future' to be natural gas and nuclear energy. That he sees no need to move quickly away from fossil fuels is indicated by his use of this quote from Vaclav Smil's 2008 book, *Global Catastrophes and Trends*:

> There is no urgency for an accelerated shift to a nonfossil fuel world: the supply of fossil fuels is adequate for generations to come; new energies are not qualitatively superior; and their production will not be substantially cheaper. The plea for an accelerated transition to nonfossil fuels results almost entirely from concerns about global climate change, but we still cannot quantify its magnitude and impact with high confidence.

The current price of oil will be enough to cause many to doubt Smil's judgement that fossil fuels will be 'adequate for generations to come'. But recent progress in extracting methane from shale means that natural gas has better prospects than anticipated a few years ago. The more important point is that even if there are adequate fossil fuels for 'generations to come', because it takes generations to reduce the size of populations to levels which could be supported in modest comfort using only renewable energy sources, the question of paramount importance is this: how much energy can, *in all likelihood*, be won from renewable sources. *In all likelihood* is a key phrase, as we should not be risking the lives of billions on a *hope* that some technological development just *may* come along.

In order to address this question, a fundamental point that needs to be answered is this: how much energy does each person need to sustain a moderately comfortable way of life?

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* *Power Hungry: the Myths of 'Green' Energy and the Real Fuels of the future* by Robert Bryce, 2010. New York: Public Affairs. $28.

To give some sense of scale, we may note that presently primary energy consumption in the USA is about 250 kilowatt hours per person per day (kWh/p/d), in the UK 125 kWh/p/d, and when world energy consumption is shared out between a world population of 6 billion, 64 kWh/p/d. World population is already well above 6 billion and is projected to rise much higher, but 6 billion is probably an appropriate number to cover those people who have a reasonable prospect of a life of comfort (rather than, for instance, a life which involves much of each day collecting firewood). Another useful kWh/p/d figure is that prior to the 1890s — before significant use of railways and electricity — primary energy use in the USA has been estimated at 89 kWh/p/d (3.7 kW/p, Hayden 2004, p20).

So long as cheap fossil fuels have been available, some nations have been taking full advantage of the facility to drive and fly thousands of miles per year, and keep their houses warm enough in winter to be in shirt-sleeves, and pleasantly cool in summer. Such things are a luxury. The amount of energy needed to maintain a 'civilized' lifestyle is a different matter. The kWh/p/d figure will vary between nations depending on their climate, but when considering the whole world, a global average figure is a useful benchmark.

Vaclav Smil — an outstanding expert in energy matters (even if he is sometimes led astray by a determination to be optimistic) — has shown that nations which enjoy a good quality of healthcare and education all use at least 48 kWh/p/d (2 kW/p). Previously this has been our chief source of guidance on the matter. It is pleasing to find that Bryce arrives at a figure in the same ballpark by a slightly different route. He writes (p60):

> In 2000, Alan Pasternak of Lawrence Livermore National Laboratory did a systematic analysis of electricity use and wealth. He used the United Nations Human Development Index — which ranks countries based on measures such as life expectancy, nutrition, health, mortality, poverty, education, and access to safe water and sanitation — as his baseline ranking system. He then compared each country's rank in the Human Development Index with its electricity consumption. Pasternak's conclusions were unequivocal: "Neither the Human Development Index nor the Gross Domestic Product of developing countries will increase without an increase in electricity use." …
>
> Pasternak's work has since been cited by many other researchers who have looked into the correlation between electricity and human development. Moreover Pasternak found that providing modest amounts of electricity per capita was not enough to assure good results. He determined that per-capita electricity consumption needed to be at least 4,000 kilowatt-hours per person per year [11 kWh/p/d] to assure the country had a Human Development Index of 0.9 or greater. That's an important distinction, because Pasternak found that "only 14.6 percent of the sample global population enjoyed a Human Development Index score of 0.9 or greater in 1997.

4,000 kWh per year per person equals 11 kWh/p/d, but to generate this amount of electricity from fossil fuels would require about 11 / 0.33 = 33 kWh/p/d. It might be thought that this would not apply when using wind turbines, but this is not so, as they can only contribute about 30%, *at most*, to an electricity grid, and can thus operate usefully only if their uncontrollable output is supplemented by 70 / 30 = 2.3 times as much input from controllable sources. With the controllable electricity coming from burning biomass (the only source of controllable electricity of possibly large enough scale), the overall transformation efficiency of wind and biomass is similar to the 0.33% posited above for fossil fuels. Thus in order to provide the *electricity* needed to obtain the Human Development Index of 0.9 or greater would require primary energy of 33 kWh/p/d.

No one would suggest that everything can be done by electricity. And in a renewable energy world, because the power density of ethanol from corn is exceedingly low, it seems likely to be necessary to produce a substitute for liquid fuels starting with electricity rather than biomass. But the process of transformation from electricity involves substantial losses, so it becomes apparent from this analysis that Smil's 48 kWh/p/d is in the ballpark for a minimum primary energy requirement for a civilized lifestyle. This is of fundamental importance as it is one element for our estimate that the world can sustain only about 2 billion people in modest comfort in a civilized lifestyle.

At present, and quite possibly for the future, the only substantial source of *primary electricity* from renewable sources is wind power. On page 65, Bryce makes some telling points about the slow process of expanding the proportion of wind power (and the other rather desultory sources) within the total grid system. He gives figures in megawatt hours per year, but kWh/p/d is an easier unit to assimilate, so I will supplement some of his figures by adding those units within square brackets. He writes:

> Between 1995 and 2008, U.S. wind output increased dramatically, going from 3,164,000 megawatt-hours per year to 52,026,000 megawatt-hours per year, for a total increase of 48,862,000 megawatt hours per year [0.45 kWh/p/d]. That's an increase of about 1,500 percent. During that same time period, solar power production (which includes solar thermal and photovoltaics) increased by 69 percent, going from 497,000 megawatt-hours to 843,000 megawatt-hours, for an increase of 346,000 megawatt-hours [0.003 kWh/p/d]. …
>
> In 1995, coal-fired power plants delivered 1,709,426,000 megawatt-hours of electricity. By 2008, coal plants were delivering 1,994,385,000 megawatt-hours per year, an increase of 284,959,000 megawatt hours [2.6 kWh/p/d].

Thus although wind and solar electricity increased by 0.453 kWh/p/d, this was only 17% of the 2.6 kWh/p/d increase in the output from coal plants occurring during the same period. If wind is gradually to climb up to an increasing proportion, it is clearly necessary for wind turbines to add *more* to the grid than is being added by controllable power. This is a graphic illustration of the general contention made in Smil's book *Energy Transitions*, that changing from one type of energy supply to another is usually a slow process, taking very many decades, and that *changing to renewable energy will be particularly slow because of its inherent disadvantages*. That is a useful point to bear in mind, but of more importance is the previously mentioned question about what are the ultimate limits to renewable energy supply. So far I have merely quoted the figure that wind can supply *at most* 30%, with the remaining 70% needing to be controllable. Bryce adds some evidence about the general problems of renewables, which is where we will now turn.

Unfortunately Bryce gets a bit confused about terminology. It helps to have some knowledge of the subject to know what he is *intending* to say. On page 96 he writes, "In the electric power business, generating plants are rated by their 'capacity factor', which is based on the amount of time they will produce power at 100 percent of their maximum output." That is so misleading as to be wrong. For one thing, generating plants are first rated by what is known as their **rated capacity**, which is the output they would generate at full power (usually at winds of about 13 m/second and above). Keeping to fairly similar concepts as used by Bryce, one could usefully define 'capacity factor' on these lines:

> Capacity factor over a specified period (or implied period, e.g. 1 year) is the *length of time* at which the plant would need to operate at its full rated capacity in order to produce the amount of electricity it actually produces, divided by the *specified time*.

The 'or implied' is necessary because when the time period is a year, the time is usually not specified explicitly. The wind industry usually defines capacity factor in terms similar to the above, but as is apparent in the case of Bryce, it often leads to the erroneous belief that wind turbines only contribute electricity when operating at full power; I would prefer:

> Capacity factor over a specified (or implied) period is the amount of electricity actually produced by a plant, divided by the amount of electricity it would produce were it to operate continuously at its rated capacity throughout that same period.

An entirely separate aspect of wind turbine operation is its 'capacity credit'. A simple definition of this would be: "The fraction of the rated capacity which can be relied upon to be available when it is likely to be needed." To arrive at the capacity credit figure requires a complicated probabilistic calculation, but the idea is simple enough. Having distinguished between capacity factor and capacity credit, we can look at some of Bryce's information and, where necessary, correct the terms he uses. Texas has been a leader in installing wind power in the USA. Referring to Texas, Bryce writes (p97):

> The Electric Reliability Council of Texas (ERCOT), which manages 85 percent of the state's electric load, pegs wind's capacity ~~factor~~ credit at less than 9 percent. In a 2007 report, the grid operator determined that just "8.7% of the installed wind capacity can be counted on as dependable capacity during the peak demand period for the next year." It added that "conventional generation must be available to provide the remaining capacity needed to meet forecast load and reserve requirements.

Bryce confirms his observations with these further comments (p98):

> In its 2008 report, CERA [Cambridge Energy Research Associates] determined that "in order to provide reliable capacity throughout the year, every megawatt of wind capacity needs to be matched up with a megawatt of despatchable capacity." Those findings were affirmed in early 2009 by Peter Lang, an engineer with forty years of experience in the energy business who is based in Canberra, Australia. In a report called "Cost and Quantity of Greenhouse Gas Emissions Avoided by Wind Generation," Lang concluded: "Because wind cannot be called up on demand, especially at the time of peak demand, installed wind generation capacity does not reduce the amount of installed conventional generating capacity required. So wind cannot contribute to reducing the capital investment in generating plants. Wind is simply an additional capital investment."

The term "despatchable capacity" is what is also referred to here as "controllable plant". Bryce goes on to refer to the conclusions of British consultant James Oswald (p99), who

> studied the potential effects of increased wind-power consumption in Britain. In a 2008 article published in the journal *Energy Policy*, Oswald and his two coauthors concluded that increased use of wind would likely cause utilities to invest in lower-efficiency gas-fired generators that would be switched on and off frequently, a move that cuts their energy efficiency and increases their emissions. Upon publication of the study, Oswald said that carbon dioxide savings from wind power "will be less than expected, because cheaper, less efficient plant will be used to support these wind power fluctuations. Neither these extra costs nor the increased carbon production are being taken into account in the government figures for wind power."

Many years ago, I showed the theoretical possibility that loss in efficiency due to having to use controllable plant capable of following the variable output of wind turbines might cause *more* fossil fuel to be used rather than *less*. But that was a simple theoretical calculation. Bryce reports on a more sophisticated analysis of the same issue (p99):

> One other analysis of the wind-carbon dioxide question deserves mention: In November 2009, Kent Hawkins, a Canadian electrical engineer, published a detailed analysis on the frequency with which gas-fired generators must be cycled on and off in order to back up wind power. Hawkins' findings: The frequent switching on and off results in more gas consumption than if there were no wind turbines at all. His analysis suggests that it would be more efficient in terms of carbon dioxide emissions to simply run combined-cycle gas turbines on a continuous

> basis than to use wind turbines backed up by gas-fired generators that are constantly being turned on and off.
>
> … During an interview, Hawkins told me that he had been studying the wind-power sector for years and had been motivated to do his analysis because "nobody has done a comprehensive study."

The main importance of this from the long-term perspective of trying to live off renewable energy is the evidence it provides about the difficulty of running a grid when it has a substantial variable input from wind turbines or other variable sources. A controllable plant normally operates well below its capacity, a capacity factor of 60% being fairly normal for fossil fuel plant. But the main reason for this reduced capacity factor is that consumer demand varies, and electrical output has to be curtailed when demand is low. The addition of wind power to the system will mean that when consumer demand is low the output from the controllable plant often has to be curtailed even further to accommodate the wind turbine input, resulting not only in the controllable plant operating at lower capacity factors (which of course is more costly), but also operating less efficiently because of the need to be able to respond to variations in demand for controllable output made even larger by variable inputs from the wind turbines.

China affords some guidance on this. Its limited grid system means that it cannot offload excess wind power to other parts of the country which are not using wind and so not troubled by excessive wind output. This makes it a useful test case. China's extensive use of coal-fired plant provides a test case for having to use biomass-fired plant. In a report from the Worldwatch Institute dated 28 February 2011, it was stated that "Chinese industrial experts have warned that wind power should not exceed 10 percent of local grid capacity to avoid the risk of a grid collapse."

From the hundreds of references to Danish wind power that I have heard on the radio or seen in magazines like *New Scientist* and *WorldWatch*, and in newspapers, I recall only one which even tried to give a realistic picture of what is widely taken to be Denmark's success in making use of wind turbines. Bryce has a chapter on Denmark, and adds some names to my list of media pundits who enthuse about wind power in general and *think* that the Danes have entirely demonstrated its potential at a penetration of at least 20%. They include Amory Lovins, whom Bryce accurately describes as a "media darling" and "among the most quoted purveyors of energy happy-talk," and *New York Times* columnist Thomas Friedman, and Joshua Green, the senior editor of *Atlantic Monthly*.

What I have continuously tried to draw to people's attention is that although in some years the amount of electricity that Denmark produces from wind turbines amounts to about a fifth of its electricity consumption, what is actually important is how much of the electricity is generates from wind can be used directly, rather than being exported to Germany, Sweden and Norway. Norway is well suited to using such surplus production since it gets 68% of its electricity from hydro, so can switch off its turbines and use the wind electricity instead. In tackling this problem, Bryce writes (p106): "In 2003, 84 percent of the wind power generated in western Denmark was exported, much of it below market-rates." Actually there are considerable problems in drawing any deductions from just *western* Denmark, and shortly we will look at the export issue more fully.

Bryce draws on a study by CEPOS, the Danish Centre for Political Studies, (p114):

> The September 2009 study by CEPOS said that Denmark's wind industry "saves neither fossil fuel consumption nor carbon dioxide emissions".

He goes on to say that the final page of the CEPOS report has a warning for the USA:

> Danish experience also suggests that a strong US wind expansion would not benefit the overall economy. It would entail substantial cost to consumers and industry and only to a lesser degree benefit a small part of the economy, namely wind turbine owners, wind shareholders and those employed in the sector.

However, since Bryce's book appeared, the CEPOS report has not gone unchallenged. There is an impressive 36 page study which can be downloaded freely from the following link: www.energyplanning.aau.dk/

The study has many authors, headed by Henrik Lund. It focuses on why the CEPOS study may be misleading. In doing so, it makes a good case for the following proposition related to 2008 (the year studied), when the electricity from wind turbines amounted to 19.3% of demand: It shows that 12.1% of demand was satisfied from wind output produced in Denmark. It goes on to point out that CEPOS assumed that all electricity exported was surplus wind output, yet it may have been a result of the controllable plant operators deciding that they could export profitably. This possibility means that Danish wind usage may go higher than 12.1%, and even though it becomes increasingly unlikely, it could even be the full 19.3% (since the exports that can be *pinned down* as caused by wind amount to a mere 0.01%). The trouble is there is no way of knowing, and all that can be said is that substantial exports occur, but the reasons cannot be clearly established. It has to be said that relying on only the CEPOS study, Bryce is not giving a fully balanced picture. However, the Lund et al report does not greatly change the picture painted by Bryce. Importantly the Lund et al report acknowledges that Denmark is a special case due to its interconnections with neighbours using mainly hydropower.

Conclusion

The most important conclusion is that my suggested 30% upper limit for wind penetration and Manfred Lenzen's 20% (Lenzen 2009, p19) are likely to be in the ballpark. Robert Bryce does well to expose how politicians and the media are dismally ill-informed on energy matters. He elucidates some of the problems of renewable energy. However, his view that natural gas and nuclear energy could be the "Real Fuels of the Future" rests mainly on hope. Anyhow the length of time that natural gas and nuclear fuel might remain the fuels of the future may be insufficient to allow for the reduction in population which is likely to be necessary when the world has to live off renewable energy alone.

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