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Investigative reporting, whether in newspapers or television, has a grand but fading tradition of asking hard questions and unveiling awkward truths. It is an expensive business, because it takes time, effort and legal protection and it will ultimately disappear if our desire to be entertained cripples our need to be informed. “We need to keep having discussions about what is important to an open society,” Heather Brook argues. “The public needs to understand that, if the media are considered just to be business operations, and if they abdicate their responsibility by reading *OK!* and celebrity gossip all day, then they can’t expect the government to be upstanding or to be held to account. It is up to everyone to be involved, keep an eye out and be aware of what is going on and be outraged when their trust is abused. But if people just sit around reading *Heat* or *Hello!* and don’t stay engaged, then they have to accept a corrupt government. A corrupt banking system. And scientists who lie.”

Margaret Hefferman in *Wilful Blindness*, p323, 2011

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<http://tinyurl.com/optj2>

INTRODUCTION

As some readers may peruse only the opening paragraph of the Introduction, I will mention at the outset that this issue of the OPT Journal is set to be the last. This has largely been a result of my health, as I had planned to continue for a few more years than the twelve during which the OPT Journal has been published. However, by coincidence, it seems not a bad time to call a halt, because I think that the OPT Journal has now covered all aspects of the overpopulation problem that it has been addressing, and there is not much more to be said. Perhaps an overview of what the OPT Journal has been trying to do is in order.

Clive Ponting's *A Green History of the World* (1991) and David and Marcia Pimentel's *Food, Energy, and Society* (1979 -2008) had already covered the essence of the problems caused by overpopulation. The first edition of the latter book suggested that a world population of two billion — living in a modest version of the American lifestyle — would be a sensible target. However, trying to peer into the future regarding the extent to which there is likely to be a transition to renewable energy, and the levels of population which could be supported without damaging the earth's support systems, remains somewhat opaque. The doyen of energy matters, Vaclav Smil, for many years thought that making a transition to renewable energy would be no problem. Recently he has changed his opinion, and makes a strong case for there being a problem in the *time* needed to make the transition. The view within this journal has been less sanguine, drawing attention to the fact that severe doubts surround prospects for ever achieving an effectual transition.

Energy has been the crux of the difficulty in deciding what a sustainable population might be. But most of what can be said at the present time has probably been said. We will have to wait to see whether the mooted transition to renewable energy takes place (in which case there will be a slow decline of human population, as climate change takes its toll, soils become exhausted, aquifers are drained, etc.) or whether it does *not* succeed (in which case there will be a precipitous drop in human population as fossil fuels run out).

It is worth calling attention to the quote on the title page. Margaret Hefferman's *Wilful Blindness* was reviewed in the October 2012 issue of the OPT Journal. The extract shown on the title page is the essence of her message. It is also the essence of the problem that faces all who strive to bring the overpopulation problem to public attention: only a few people want to listen, which is something the popular media know only too well.

Pages 4–5 round off the extracts from Chapter 15, *Soil Erosion: A Food and Environmental Threat*, of David and Marcia Pimentel's book *Food, Energy, and Society*. The title of the chapter calls attention to one of several reasons that even if we make a successful transition to renewable energy, in the longer term a much smaller human population is unavoidable due to the damage humans cause to the environment.

On pages 6–9 Walter Youngquist lays out what is presently known about fracking. As with a transition to renewable energy, there can be no certainty about the future, but presented here is a balanced view of the probable impact of fracking from someone with unrivalled experience in geology and petroleum production.

Walter Youngquist kindly sent me *The Big Flatline: Oil and the No-Growth Economy* by Jeff Rubin, reviewed on pages 10-15. Rubin has been outstandingly successful in the world of finance, but takes a dispassionate view of how the industry makes money. The BBC features discussions about the reasons for the financial crisis, but globalization and deregulation are rarely cited as the main reasons (indeed deregulation seems to be close to a taboo topic). Rubin makes an unanswerable case for these two being the main culprits.

Arnold Pacey is a historian with a scientific background and extensive experience in the environmental movement. His *Personal view of climate change* (pp. 16–19) echoes many of the points made in this journal over the years, and gives a similar historical perspective of recurrent problems to Clive Ponting in his *A Green History of the World*.

The main thrust of this journal has been to try to establish levels of sustainable population. The next two pieces, *Thermodynamic Footprints and Limits to Population*, and *Ecological Footprints and Limits to Population*, reprise this, showing that there is close agreement between (1) the limits arising from carbon emissions, and (2) the need to provide energy from renewable sources — at least on the basis of present knowledge of what is possible.

William Dickinson, former head of the **Washington Post Writers Group**, has been worrying away at the overpopulation problem for many years, and commendably continues to do so at the age of 82. His short article, on pages 24–25, *The "Baby Bust" Fallacy*, provides a good illustration of a constantly recurring theme of the OPT Journal and Margaret Heffer's book : failings of the human mind are the fundamental problem.

Finally, pp. 26–28, is a review of a piece by Quirin Schiermeier in *Nature*, titled *Germany's Energy Gamble*. He looks at the very important experiment that Germany is carrying out to see how far renewable energy might be able to replace fossil fuels.

Acknowledgements: Wrapping up the OPT Journal calls for a general acknowledgement of the help I have received. David Pimentel and Walter Youngquist have been great sources of support throughout. Martin Desvaux has helped me draft several articles as well as producing the digest of the fundamentally important *A Green History of the World*. Harry Cripps has helped me with energy matters. Val Stevens has fed me with relevant articles from *Nature*. Eric Rimmer has thrown up thought provoking ideas which we have worked on together. Yvette Willey, as well as being a wonderful proof-reader, has made my OPT work much easier in several ways. We have both been glad to keep alive the memory of our founder David Willey, who had the insight to see the fundamental importance of nations having a target to aim for in terms of the size of population which could be sustained in a civilized lifestyle. Over the years, estimates in the OPT Journal have not significantly changed from those that David and I arrived at, but hopefully some light has been shed on the uncertainties surrounding a successful transition to renewable energy, which so many people still take for granted.

Note from the Chairman and Chief Executive

Population Matters would like to express its heartfelt thanks to Andrew for his sterling work in editing the Journal over the last twelve years. We invite readers to let us know whether they feel that Population Matters should produce a publication of this or a similar type in the future and, if so, what general form and content they would like to see. Please send your comments to enquiries@populationmatters.org.

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. The Optimum Population Trust now operates under the name *Population Matters*. The website of Population Matters is to be found at www.populationmatters.org

FOOD, ENERGY, AND SOCIETY (3rd edition), Part 10

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

Chapter 15 (continued). Soil Erosion: A Food and Environmental Threat

EFFECTS OF EROSION ON TERRESTRIAL ECOSYSTEMS

207.0 Soil erosion reduces the productivity of terrestrial ecosystems. In order of importance, soil erosion increases water runoff thereby decreasing the water infiltration and the water-storage capacity of the soil. Also, during the erosion process organic matter and essential plant nutrients are removed from the soil and the soil depth is reduced. These changes not only inhibit vegetative growth, but reduce the presence of valuable biota and the overall biodiversity in the soil.

WATER AVAILABILITY

207.5 Water is a prime limiting factor of productivity in all terrestrial ecosystems because all vegetation requires enormous quantities of water for its growth and for the production of fruit. For instance, 1 ha of corn or wheat will transpire more than 5–7 million L of water each growing season and lose an additional 2 million L of water by evaporation from the soil. [AF. A total of say 8 million L is equivalent to a depth of 800 mm] During erosion by rainfall, the amount of water runoff significantly increases, with less water entering the soil, and less water available to support the growing vegetation.

NUTRIENT LOSS

207.8 Eroded soil carries away vital plant nutrients such a nitrogen, phosphorus, potassium, and calcium. Typically, eroding soil contains about three times more nutrients than are left in the remaining soil. A ton of fertile topsoil averages 1–6 kg of nitrogen, 1–3 kg of phosphorus, and 2–30 kg of potassium, whereas the soil on eroded land has average nitrogen levels of only 0.1–0.5 kg/t.

When nutrient resources are so depleted by erosion, plant growth is stunted and overall productivity declines. Nutrient deficient soils produce 15%–30% lower crop yields than uneroded soils.

To offset the nutrient losses that erosion inflicts on crop production, large quantities of fertilizers are often applied. Troeh et al. estimate that the lost soil nutrients cost U.S. agriculture $20 billion annually. If the soil base is relatively deep, about 300 mm, and if only about 10 to 20 t of soil are lost per hectare per year, the lost nutrients can be replaced with the application of commercial fertilizers or livestock manure. However, this replacement strategy is expensive for the farmer and nation and usually not affordable by poor farmers. Not only are the fertilizer inputs fossil-energy dependent, but these chemicals can also harm human health and pollute the environment.

SOIL ORGANIC MATTER

208.3 Fertile soils typically contain about 1000 tons of organic matter per hectare (or 4% of the total soil weight). About 95% of the soil nitrogen and 25%–50% of the phosphorus are contained in the soil organic matter. … Both wind and water erosion selectively remove the fine organic particles in the soil, leaving behind large soil particles and stones. Several studies have demonstrated that the soil removed by either erosion is 1.3–5 times richer in organic matter than the remaining soil left behind. For example, the reduction of soil organic matter from 1.4% to 0.9% lowered the yield potential for grain by 50%.

208.8 Once the organic matter layer is depleted, the productivity of our ecosystem, as measured by plant biomass, declines both because of the degraded soil structure and the depletion of nutrients contained in the organic matter. In addition to low yields, the total biomass of the biota and overall biodiversity of these ecosystems are substantially reduced.

Collectively and independently the diverse impacts of erosion reduce crop biomass, both because of degraded soil structure and nutrient depletion. For example, erosion reduced corn productivity by 9%–18% in Indiana, 0%–24% in Illinois and Indiana, 25%–65% in the southern Piedmont of Georgia, and 21% in Michigan. In the Philippines over the past 15 years, erosion caused declines in corn production by as much as 80%.

BIOMASS AND BIODIVERSITY

209.2 The biological diversity existing in any ecosystem is related directly to the amount of living and non-living organic matter present in the ecosystem. … Along with plants and animals, microbes are a vital component of the soil and constitute a large percentage of the soil biomass. One square meter of soil may support about 200,000 arthropods and enchytraeids plus billions of microbes. A hectare of productive soil may have a biomass of invertebrates and microbes weighing up to 10,000 kg. In addition, soil bacteria and fungi add 4000–5000 species and in this way contribute significantly to the biodiversity especially in moist, organic forest soils.

210.8 The soil biota perform many beneficial activities that improve soil quality and ultimately its productivity. For example, soil biota recycle basic nutrients required by plants for their growth. In addition, the tunneling and burrowing activities of earthworms and other soil biota enhance productivity by increasing water infiltration into the soil. Earthworms, for instance, may produce up to 220 tunnel openings per square meter (3–5 mm in diameter). These channels enable water to infiltrate rapidly into soil.

Ed. From this amazingly comprehensive book, we have covered only fifteen of the twenty-three chapters, but the extracts given in this ten part series have covered the most essential matters from our perspective. Much of the rest of the book is concerned with looking at energy matters, with a particular focus on biofuels, analysing both their energy return on energy invested and their power density. This is a subject that has been covered comprehensively in previous editions of the OPT Journal. Articles in the journal have made essentially the same assessments as those to be found in *Food, Energy, and Society*: the energy return on biofuels is hopelessly low, and power densities are also low relative to those available from fossil fuels. Where the OPT Journal has gone further than this fine book is in trying to assess the effect of the variable and uncontrollable inputs (reflected in low capacity factors) of photovoltaics, solar thermal, and wind turbines.

"FRACKING" FACTS

by Walter Youngquist. Emeritus member American Association of Petroleum Geologists. Eugene, Oregon. Author of the book *GeoDestinies*, the second edition of which is imminent.

Recently in the United States we have had a plethora of articles, mostly highly optimistic, on the effect of the technology of ‘fracking’ shales to produce oi1 and natura1 gas and eventually eliminate the need to import both. Prominent is the recent statement by the International Energy Agency that U. S. oil production could exceed that of Saudi Arabia by 2020. This has been enthusiastically interpreted by some people to mean the United States could be energy independent and therefore oil independent by 2020. Worldwide there is also interest in what fracking might do for oil and gas supplies.

Hydraulic fracturing or fracking of oil and gas reservoirs is not a new technology. It has been used for more than 40 years. What is new is the discovery that the source beds of oil and natural gas (organic rich shales), previously thought of only as rocks from which oil and gas would migrate to porous and permeable reservoir rocks, could themselves be reservoirs and made to produce oil and gas. This is done by a combination of lateral drilling and the high pressure injection of a mixture of water, chemicals, and sand, fracturing the shale and keeping the fractures open by means of the sand. Shales are widespread worldwide, and this technology has greatly enlarged the exploration frontier for oil and gas.

As experience develops with fracking of shales, some facts are beginning to emerge relative to cost of the wells, initial production rate and subsequent rate of production decline, and also as to the possible impact of this technology on both the United States’ and world oil and gas supplies, and on geopolitical relationships.

Some fracking facts : initial production decline rates are high. In the Bakken shale wells of North Dakota a typical well coming in at 367 barrels per day (bpd) will be down to 136 bpd by year end, a decline of 63 percent. Just to maintain the production rate, 94 wells have to be completed each month. To maximize production from the Bakken ‘play’, as many as 40,000 wells are projected to be drilled. These wells cost from four to 10 times more than conventional wells, and therefore depend on a continued high price of oil. These statistics broadly apply to all U. S. and world shale oil and gas developments.

The big fracking ‘play’ in Texas is in the Eagle Ford shale. It has wells coming into production at a rate as high as 4,000 bpd, but the decline rate the first year is as much as 75 percent. To fully exploit the Eagle Ford, some 4,000 additional wells are expected to be drilled beyond the more than 500 wells already completed. The redeeming economic feature of fracked shale oil production is that the production curve ‘tail’ is apparently quite long at a low rate of production. However, we do not have the years of experience to determine how long the ‘tail’ is, its ultimate total oil production, and the long term decline rate ultimately leading to abandonment of the well.

The United States currently uses nearly 20 million barrels of oil a day. In regard to the view that the United States might exceed Saudi oil production by means of fracking shale production added to conventional oil production, and this could make the United States oil self-sufficient, and therefore energy independent, the facts are these: Saudi Arabia currently produces approximately 9.5 million barrels of oil a day. 80 percent of the United States addition to oil supplies from fracking is from the two plays, the Bakken and the Eagle Ford, each of which is eventually expected to possibly produce a million barrels a day. Assuming that the two oil plays would achieve peak production at the same time, this would add two million barrels a day to current United States' production of seven million barrels a day. The total then would be nine million barrels a day, still less than the current Saudi oil production, and far short of the United States' daily consumption of 20 million barrels. This projected gap between the United States' and Saudi oil production, even with U. S. fracking oil added, is likely to continue and possibly enlarge in the next decade. Saudi Arabia now has some 2.7 million barrels of production shut in. The United States has no shut in production.

Oil and gas volumes are commonly reported by industry as **reserves** and **resources**. The distinction between the two is very important but is frequently not understood. Reserves are the amount of oil or gas (or other Earth resource) that may be recovered economically by existing technology and at current prices. Resources are the total amount of a given commodity that exists in that discovered deposit.

Technology may improve and prices may rise, and this combination may move more of a given resource into the category of reserves over time. The recovery of oil from the fracking technology is dependent on consistently high prices. This determines the 'recovery factor', which is commonly stated as a percentage of the resource.

For example, the Monterey Shale of California is estimated to have roughly 500 billion barrels of oil in place (resources). However, only about 15 billion barrels, approximately three percent, are estimated to be economically recoverable (reserves). The Eagle Ford shale has an estimated 27 billion barrels of oil in place, but the recovery factor is only six percent. A misunderstanding of the distinction between reserves and resources may lead to an enthusiastic overestimate of the size of a given mineral or energy discovery and what it may do for an economy.

Worldwide, with fracking technology only about five percent of the oil, and ten percent of the gas in place are estimated to be economically recoverable. Some shales are oil rich with modest amounts of associated gas. Most shales produce only gas. Gas occurs in a greater variety of geological settings than does oil so it is more widespread and abundant than oil in its distribution. The simple natural gas molecule, methane (CH_4), is lighter than air and much smaller than the large complex oil molecule. This enables gas to be more mobile than oil and can be more easily released by fracking than can oil. This fact is important in considering the future production of these two energy sources.

Whereas the fracking technology was developed and is now extensively implemented in the United States, it is only beginning to be used in other places around the world. But its continued development has geopolitical implications as it relates to energy dependency. Poland, for example, would like to be independent of Russia for its gas supply and has already leased tracts in the Baltic basin for gas development. ExxonMobil was an early entrant, but after two unsuccessful wells has abandoned further exploration plans. Other companies continue to explore.

Elsewhere in Europe, France has banned all fracking, fearing excessive environmental impacts from the technology. Germany is considering fracking as are other European countries, along with Great Britain. The concerns largely are in regard to possible groundwater contamination, the use of huge amounts of water, proper disposal of waste water that occurs in large volumes, and small earthquakes that have been noted in some areas of fracking. China is moving slowly in using this technology, but with greatly increasing demand for energy and the intent to try to decrease its dependence on coal to improve its currently very bad air quality, it is gradually embracing fracking.

China's potential for technically recovering gas from fracking is the largest of any country, with 1,275 trillion cubic feet, exceeding even the United States, which is in second place with 862 trillion cubic feet.

Regionally, the estimated worldwide technically recoverable natural gas in trillions of cubic feet is: Americas 3,143 (Argentina with 774 is next to the United States), Asia-Pacific 1,625; Africa 1,059; Europe 989; Australia 396 (Chevron has already invested $349 million in shale gas there), and Middle East 141. Note that these are technically recoverable figures and ignore the economics. We are finding that at least some technically recoverable oil and gas from fracking is not currently economic. How much will be economic in the future, as elsewhere stated, is dependent considerably on price, which changes over time and differs regionally.

In summary, the fracking of source beds for both oil and gas will likely continue to expand and then mature as an industry for several decades. It will, to some degree, alter the current energy balance for various countries, and for a time reduce but not eliminate the need for Middle East oil and Russian gas.

For the United States, oil from fracking shales will reduce for a time but not eliminate the need to import oil. We will be independent from foreign oil imports only when the last barrel of oil available to import is imported. Thus, contrary to much popular enthusiasm, fracking will not make the U. S. oil independent (and therefore not energy independent), but it will help a bit on the import bill, the largest single item in our current negative balance of trade. United States' gas supply situation, however, is greatly improved and will more than meet the current domestic demand of 25 trillion cubic feet/year. Ample natural gas supplies (extensively used as feedstock for both chemicals and plastics) will favorably impact the United States' industrial complex for some years into the future, and may even provide gas for export, improving the balance of trade.

Fracking will for a time change the world geopolitical scene regarding oil and gas supplies, and will provide some economies with relatively cheap fuel for many years. Producing oil and gas by fracking from shales around the world will take considerable time to be fully implemented. Rates of development will differ depending on political and economic circumstances, and how fast the technology can be transferred and the necessary equipment built and be put on site. But for all that fracking might do for oil and gas supplies, the countries that are now importers will probably continue to be net importers, but perhaps for a time to a lesser extent.

OPEC will not become obsolete and is very likely to still be the last oil man standing. In the meantime, the oil and gas industry will have a new if transient lease on life providing many jobs and opportunities for a variety of industrial developments in many regions for several decades to come. However, in the longer term, oil, the current world major energy source, is finite, and its inevitable ultimate economic availability declining to insignificance will have a profound impact on world economies, especially in agricultural production and our individual lifestyles. No comprehensive substitute is now visible.

Walter Youngquist wrote the above before a valuable book on not only fracking but also all non-conventional means of extracting oil and gas was published. The 166 page book is by David Hughes, with the title of *Drill, Baby, Drill* (2013). I am fortunate enough to have a copy (sent to me by Walter). It is a remarkably impressive book, with charts on nearly every other page, many of them giving details of the oil and gas production histories of all the more important ‘plays’ — as productive areas of fracking are called, while others show the locations where drilling is taking place. Hughes covers not only shale gas, tight oil (shale oil), tar sands, but also “other resources.” Under the last he includes “oil shale (not to be confused with shale oil), coal bed methane, gas hydrates, and Arctic oil and gas — as well as technologies such like coal- and gas-to-liquids, and *in situ* coal gasification.” Having considered these in detail, he concludes that they are “likely to be a small player in terms of rate of supply for the foreseeable future even though they have large *in situ* sources.” Hughes frequently stresses the difference between rate of supply and the *in situ* resource — a very important distinction. The book is a truly amazing work of scholarship.

Although Youngquist’s article was written before *Drill, Baby, Drill* was published, it is not surprising that Youngquist’s overview is in line with Hughes, as Hughes is a long-time friend and fellow petroleum geologist.

Reference

Hughes, J.D. 2013. *Drill, Baby Drill: Can Unconventional Fuels Usher in a New Era of Energy Abundance.* Post Carbon Institute.

THE BIG FLATLINE: OIL AND THE NO-GROWTH ECONOMY

by Jeff Rubin.* A review by Andrew Ferguson

Abstract. Much that Jeff Rubin writes has been foreshadowed in previous issues of the OPT Journal, but it is very encouraging to see such views coming from an economist. Moreover Rubin has long experience of working in the financial world, so it carries conviction when he reveals the way in which globalization and deregulation have led us into the current crisis. He only fails in that he does not take a longer view than the relatively short time that oil production will continue to flatline, before it starts to decline.

For nearly twenty years, Jeff Rubin, a Canadian, was the chief economist at CIBC World Markets. Soon after departing from them in 2009, he published his first book, *Why Your World Is About to Get a Whole Lot Smaller*. His latest book, *The Big Flatline*, covers ground that will be familiar to OPT Journal readers, but nevertheless it is a good read, bringing some important further points to light. What makes the views expressed singular is the fact that Jeff Rubin is an economist, and yet realizes the fundamental importance of the fact that the world's resources are finite. He thus joins an elite band of economists, which includes Thomas Malthus, John Stuart Mill, Kenneth Boulding and — still with us today — Herman Daly. They are all good theoretical economists, but Jeff Rubin adds the further distinction of having been in the front ranks of the financial world for a long time.

In reviewing what he has written, let us look at what he has to say about (a) the current political and economic forces pervading society, (b) peak oil, (c) climate change, (d) the reasons for the recent collapse of the financial world, and (e) what all this means for the future.

The current political and economic forces pervading society

Rubin's understanding of the current *belief* in growth is well expressed in this paragraph:

> Growth is the Holy Grail of modern societies. It's the common denominator underlying nearly every action taken by corporations and governments. Whether it's the sales manager at your local electronics store, the developer of a new housing project or a finance minister trying to close a huge budget deficit, each one prays at the altar of growth. …
>
> For the economics profession, the notion of a world without growth is pure science fiction. While most economists now acknowledge that expensive energy curtails GDP, the majority also believe that technological innovations will allow us to leap over the hurdles presented by resource scarcity. (pp.11-12)

Rubin gives some statistics to show the levels to which governments will go to encourage growth to continue:

> In the aftermath of the financial crisis of 2008, Greece was not alone. Governments around the world piled up debt in a double-barreled attempt to fight the recession and save a global banking system on the edge of collapse. And now countries are left with huge budget shortfalls that dwarf anything we have seen in the postwar era.

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* *The Big Flatline: Oil and the No-Growth Economy*, by Jeff Rubin. 2012. NY: Palgrave Macmillan. Hardback, £17, $27.

> At its worst, Ireland's annual budget deficit accounted for nearly a third of its GDP. Portugal's deficit in 2010 was 8.6 percent of its GDP, down from 10 percent a year earlier. Severe austerity measures will help out that figure into the range of 4.5 percent in 2011. Similar measures, though, aren't working as well in Greece, where a shrinking economy means the country's annual budgetary shortfall remains stuck in the double-digit range, where it has been for the last several years. To put those numbers in perspective, the European Monetary Union (EMU) sets a ceiling on budget deficits of 3 percent of GDP as part of its criteria for inclusion in the eurozone. …
>
> In the United States, the Obama administration is running a budget deficit of more than a trillion dollars. That's caused the country's debt-to-GDP ratio to nearly double in the last three years to more than 70%, as Washington has strung together a series of record deficits to help fight the effects of the recession. (p.40)

The US deficit, of more than a trillion dollars, exceeds $3000 a year for each man woman and child. How long would people voluntarily continue to burden themselves with such debts annually? More importantly, can success crown these government efforts to grow? That is where Rubin parts company with 99% of his fellow economists. He says:

> Economic growth has always been competitive, but never to this point has been zero sum. Triple-digit oil prices are an unmistakable sign that we are entering a very different world from the one we have known. In the past, an abundance of resources allowed for much more economic growth than is possible today. Even if China's economy expanded at twice the pace of the US economy, what really mattered was that both were getting bigger. Mutually occurring growth was feasible in the last decade because we were not yet in a zero-sum world. (p.150).

That is a sound assessment of the current political and economic forces pervading society. Rubin's assertion that we are entering a very different world (namely a *zero sum* world, where one person's gain must be another's loss) is based on triple-digit oil prices, so let us see what he has to say about peak oil.

Peak oil

A dozen good books have been written by geologists and associated experts about the fact that the peak of oil production would be reached about 2005. The recent development of fracking has led some people, including many in the media, to think that the production of oil can continue to increase so as to meet demand for several more decades. This hope, and the hope that new sources such as deep water drilling and Arctic oil can replace the old prolific sources, have been looked at with devastating expertise by J. David Hughes in his recent book *Drill, Baby, Drill* (2013). Those hopes turn out to be delusional.

Rubin does not attempt to cite all this work, but cements his conclusion that three-digit oil (i.e. at least $100 a barrel) is here to stay with a few telling points, for instance:

> At its peak, easy-to-refine crude from Spindletop literally gushed out of the ground at the astounding rate of 75,000 barrels a day. To put that in perspective, in 2010 the average daily production of a Texas oil well was 6 barrels. In total, the state's 158,000 wells produced just shy of 1 million barrels a day. After a hundred years of exploration, there are no Spindletops left to find. This said, the global energy industry is spending hundreds of billions pulling oil out of places such as Canada's tar sands and the Faja. …
>
> A lack of new supply finally spurred the IEA to remove its rose-colored glasses and acknowledge the finite nature of the reserves the world would be able to practically

> exploit. According to IEA's 2010 *World Energy Outlook*, 80 percent of all the oil fields operating today won't be producing in another twenty-five years. (p.91)

The extent to which "pulling oil out of places such as Canada's tar sands" is inferior to drilling oil wells is brought out by another mind-numbing observation given by Rubin:

> In northern Alberta, Syncrude's tar sands mining operation moves 30 billion tons of earth every year, twice the amount of sediment that flows down all of the world's rivers annually. (p.183)

Climate change

Rubin is a realist about carbon emissions:

> Governments around the world have long thought that the path to a greener atmosphere begins with decarbonizing our energy systems — electricity generation in particular. Despite efforts to usher in more renewable power generation, however, the amount of carbon emitted per unit of electricity produced has actually increased by 6 percent globally in the last two decades. Even environmentally unfriendly coal still commands a full 41 percent share of global power generation. (p.215)

Rubin also realizes that with China having to import coal, increasing energy use cannot continue for much longer due to the availability of resources:

> The Chinese Electricity Council warned that in the first four months of 2011 alone, the five largest power-generating groups in the country lost more than 10 billion yuan after they were forbidden from passing rising coal costs on to customers.
>
> Chinese authorities can cap power prices for the time being, but that will only bankrupt the country's coal-fired utilities. At the same time, China's industries and consumers are living under a subsidized umbrella of false power costs. Eventually, resource scarcity will assert itself. Both China and India will have to ration power, which will put the brakes on economic activity. That process has already started with the rolling blackouts that are now a permanent feature of the economic landscape in those countries. (p.216)

He draws attention to another place where electricity is a problem:

> In the summer of 2011, half of Pakistan's power generating capacity was off line because utilities couldn't pay for fuel. Cities in Pakistan are routinely subjected to electricity outages that last upward of fourteen hours. In rural areas, the power rationing is even more extreme, and blackouts can last even longer. (p.188)

Readers of the OPT Journal may recall the article *Rutledge's Hypothesis*, in the October 2008 issue of the journal, in which there was a review of Dr. David Rutledge's Caltech lecture on the subject of energy reserves. In the review's Abstract, it was stated:

> It is suggested here that while this hypothesis may not be right, it behoves us to take precautionary action on the basis of it being correct, in part because the action which it is appropriate to take is the same as that which needs to be taken anyway to reduce the risk of catastrophic climate change.

Rubin having referred to Rutledge's work, comes to the conclusion that some of the IPCC's scenarios are totally unrealistic because there is not that amount of carbon likely to be accessible to release. This was the conclusion that Rutledge reached on the basis of his hypothesis that the peak production of gas and coal could be assessed by the same method as has been successful with oil. Rubin makes use of Rutledge's work and succinctly makes the following point about the likely lack of realism in the IPCC scenarios:

> He [Rutledge] estimates the total amount of coal available to be mined (past, present and future) at 662 billion tons. That is well short of the World Energy Council's calculations, which put that same figure at 1,162 billion tons. The maximum cumulative coal production assumed by an IPCC scenario is 3,500 billion tons. …
>
> Whether or not Rutledge's numbers are exact is not the point. If his basic assertion that world coal reserves are considerably overestimated is accurate, the IPCC scenarios become much less frightening. (pp.217-8)

At the end of the article *on Rutledge's Hypothesis*, it was suggested that although the amount of carbon available to release might be such as to keep the world from suffering the worst ravages of climate change, efforts should be made to slow down the release. Three options were proposed, but none judged to be likely to be implemented due to the political difficulties involved. Rubin appears to make a similar judgement. In his previous book he suggested a carbon tariff, but in this book he puts his hopes on high prices having the necessary effect.

Thus within the limits of present knowledge, Rubin is sound on climate change. As an economist specialising in finance, it is not surprising that the next section is where he shines.

The reasons for the recent collapse of the financial world

Rubin understands the effects of globalization with a clarity that appears to be very rare among economists and politicians:

> Globalization ushered in a massive redistribution of income among countries. A huge pool of cheap labor brought companies, ranging from auto plants to call centres, to places such as China and India. The shift was a boon for those countries and the bottom line of multinational corporations, but someone always gets the short end of the stick. In this case, it was north American workers. Not only did they lose their jobs, but their bargaining power also took a hit each time another overseas factory opened.
>
> … When capital is mobile and labor is not, the playing field tilts toward footloose multinational firms at the expense of local wage earners. (pp.163-4)

The late James Goldsmith understood the problem well, and wrote about it eloquently (1995). Also it was covered in *The Social and Ecological Consequences of Globalization*, which appeared in the April 2003 issue of the OPT Journal. Nevertheless, it is pleasing to find an economist — especially one who for long flourished in the financial world — prepared to express the matter so clearly.

In addition to globalization, and perhaps even more important in precipitating the financial crisis, is the fact of deregulation. Rubin sets this out with perfect clarity:

> In the 1980s, the same tide of deregulation championed by Thatcher in Britain and Ronald Reagan in the United States swept across other OECD countries, including Canada. Until then, the financial services industry had been divided into four separate pillars; banks, trust companies, brokerage firms and insurance. Cross-ownership was prohibited. When the restrictions preventing banks from owning brokerage houses were lifted, the major Canadian banks jumped at the chance to get into the lucrative business of investment banking.
>
> In 1988, the Canadian Imperial Bank of Commerce (CIBC) scooped up Wood Gundy and used it to build an investment banking platform. Like many in the brokerage industry, the Wood Gundy executives were a sharp and hungry bunch. It didn't take long for a sort of reverse takeover to unfold at CIBC. The bank's senior executive positions were soon filled with former Wood Gundy staff, who imported the

> same aggressive deal-making culture that worked in the brokerage business to the bank as a whole.
>
> Even more important than the change in corporate culture was the transformation in the way deals were funded. Instead of relying on a limited pool of partners' capital, former Wood Gundy bankers could now cut deals using the comparatively limitless funds provided by the bank's balance sheet. …
>
> In this new world of investment banking, the rewards for chasing big deals far outweighed the consequences when something went sour. When CIBC paid $2 billion to settle a law suit stemming from its intimate involvement with Enron, it wasn't the partners' capital that was at risk, as in the days of Wood Gundy. Instead, CIBC shareholders absorbed the losses. Similarly, when CIBC wrote off billions as a result of its investment bank's exposure to the US subprime mortgage market, it was once again the bank's shareholders who took it on the chin. …
>
> If access to public money wasn't enough to supersize Wall Street deals, American regulators also contributed to the trend, easing the rules limiting the amount of money investment banks could borrow, allowing banks to pile up debt that dwarfed their equity. …
>
> By the time that Lehman Brothers and Bear Stearns blew up, their leverage had climbed to more than thirty times equity. At that level of debt, even small adverse market moves could send an investment bank into insolvency. After years of deregulation, no one should have been surprised. Give investment bankers all the financial incentive in the world to borrow money, strip away most of the rules and consequences, and the real question is how these brokerage houses stayed afloat as long as they did. Wall Street's only salvation was that it had become too big to fail. (pp.165-167)

I expect that many readers will have surmised that this sort of thing was at the root of the financial crisis, yet somewhat suspended their judgement on account of finding it hard to believe that our politicians and the regulators they appointed could have been so blind to the risks they were piling up by deregulation. Thus it is very useful to have the matter clearly spelt out by someone so experienced in the field as Jeff Rubin.

What all this means for the future

Rubin makes it clear why he thinks that triple-digit oil prices will make it impossible to expand the economy, and that we will all need to live more frugally. But when he comes to expound his views on this, it is clear that he is very selective in the evidence he brings to the fore; he chooses a short perspective, namely the period during which there is likely to be his "big flatline" in energy supply, thus avoiding the far more difficult period when the energy, particularly in the useful form of oil, is likely to be steadily falling.

He suggests only that life can be just as pleasant if we live more frugally, e.g. with smaller houses and cars. This would be of marginal help, and likely will be forced upon us as everything becomes more expensive due to rising fuel and food prices. Rubin makes the point that food has risen in price more rapidly than energy:

> Higher energy prices flow directly into higher food prices. In fact, world food prices are rising even faster than energy costs. The UN's food price tracking index reached a new record in January 2011, eclipsing the previous high set in 2008. Back then, soaring food prices sparked riots in the developing world. Turn the clock forward to 2011, and it should come as no surprise that countries in the Middle East and North Africa were again convulsing with social and political unrest. (p.189)

After making these observations, Rubin says that rising food prices will certainly be a problem for the developing world, but not so much for the developed world, as it only pays a small proportion of its income for food. While this is substantially true, it will not seem a small problem to either the US government or that of the UK, which have to set minimum welfare payments at a level sufficient to allow people a healthy diet as well as to provide warmth and shelter.

Moreover, were Rubin to have extended his view beyond the period of his "big flatline", to the period of falling energy supplies, then a list of further problems arise which indicate dangerous waters ahead, for instance:

a) As noted in my review of Vaclav Smil's 1993 book *China's Environmental Crisis* (OPTJ 13/1, p.22), Smil stated that, "Even if the rich meat-eating Western nations were to revert to predominantly vegetarian diets ... global farming without synthetic nitrogen would feed no more than 3.5 billion people, or roughly two-thirds of the current total." Yet synthetic nitrogen requires a lot of energy to produce and distribute.

b) The large increase in cereal production that has been made possible with Norman Borlaug's short-stalk variants is only possible with large use of fertilizers, plus irrigation. Both of these become more difficult as energy becomes scarce.

c) Falling water tables and the drawing down of aquifers are making irrigation more expensive and impossible in some places.

d) Ongoing soil erosion and desertification are major reasons for projecting lower food production in the not so distant future.

e) A substantial amount of agriculture has been made possible by the ability to prepare ground and harvest it expeditiously, as well as applying appropriate fungicides and pesticides, all of which may become near to impossible as energy becomes excessively expensive.

f) Even at this time, about half the world is suffering from malnutrition.

If Rubin were to have taken just a slightly longer view, he would need to take those facts into account. However Rubin's book is an excellent assessment of the importance of oil in our modern world, and his insight into the forces that led the world into the current financial crisis is outstanding — definitely superior to a BBC television series about bankers, which altogether lasted for three hours. The BBC stressed that the bankers had completely abandoned their moral compass, but hardly touched on the reason for this. As Rubin explains with great clarity, it was an almost inevitable result of deregulation.

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A PERSONAL VIEW OF CLIMATE CHANGE

by Arnold Pacey

Climate in context

Interactions between the natural environment, climate and the growing human population have troubled me for over forty years. I even remember giving a talk on "the population explosion" in 1968. But I also felt baffled by the way so many issues interlock. Working for Oxfam between 1973 and 1975, I gained a better perspective, because Oxfam's view of population had recently developed in new directions and it was doing more on family planning. I was asked to edit guidelines on the subject for a policy handbook, while another duty was to keep colleagues briefed about climate change in the drought-prone areas of Ethiopia and the West African Sahel where Oxfam was involved in famine relief.

In these parts of Africa the climate is mostly too dry for conventional farming, but there is enough vegetation, including scrubby woodland, for some livestock to be kept – cattle, camels, goats. But, from the late 1960s and into the '70s, rainfall in the Sahel was well below average, and herders were finding it more and more difficult to pasture and water their animals. Many livestock died, leaving people without subsistence. Some observers argued that drought in the Sahel was caused by people keeping too many animals and allowing the land to be over-grazed. In places that had been lightly wooded, almost no trees were left. There was less moisture in the atmosphere as a result, and this contributed to the lack of rainfall.

Another view was that there were natural cyclic variations in rainfall, and that severe drought was a recurring event. In northern Mali, a part of the Sahel region that was particularly affected, there had been times of particularly good rainfall in the 1920s and around 1950 with drier periods between. But from the mid-1960s a downward trend in rainfall was more serious than any previous dips in the cycle, and there was a drought of unprecedented severity in the 1980s, now regarded as one of the effects of global climate change.

The question of human-induced (anthropogenic) effects

The possibility that climate is affected by burning fossil fuels and the build-up of atmospheric carbon dioxide was recognised as a possibility over a century ago. There was clear evidence even then that increased carbon dioxide in the atmosphere tends to trap the sun's heat near the surface of the earth, giving rise to a warming effect, like the glass in a greenhouse.

Recently, more evidence has been obtained from cores drilled into the Greenland ice-cap, which reach down into ice formed 20,000 years ago. These show that carbon dioxide concentrations in the atmosphere have varied greatly over time. Low concentrations have coincided with the coldest phases in ice ages, and increased atmospheric carbon dioxide has helped sustain the higher temperatures of inter-glacial warm periods.

Climate sceptics have to argue against a great deal of research on such matters if they are going to deny that burning fossil fuels can have an effect on climate, but when it comes to saying how big this warming effect may be, and how it may develop in the future, there is a degree of confusion as well as disagreement.

The confusion arises because many statements refer to *average* conditions over the whole world whereas there are many local and regional exceptions to global trends. For example, as surface temperatures across the world increase – on average – there is more evaporation from the sea and hence more water vapour in the atmosphere and an increase in cloud cover. That makes some places cooler as the cloud blocks out the sun and reflects solar radiation back into space. Increased water vapour in the atmosphere ought also to lead to increased rainfall and – on average – this is what is happening. But there are also places that get hotter and drier – such as the Sahel and other parts of the world that have long been prone to drought.

Climate models

Among the most powerful tools scientists have for weighing up different influences on climate, natural and anthropogenic, are computer simulations or models of the behaviour of the atmosphere. Climate sceptics are particularly critical of these models, arguing that they give exaggerated forecasts of temperature increase, and under-estimate natural variations in climate.

However, climate models are constantly being tested against observations, and one test is whether they can account for regional differences. In this respect, all the models show how and why climatic warming is more evident at the poles than elsewhere, particularly in the melting sea-ice around the North Pole.

A warmer Arctic Ocean also profoundly affects the weather systems of the northern hemisphere and recent changes have been associated with episodes of cool, unsettled weather in parts of Britain and northern Europe. That is one regional effect that climate models represent quite well though it is only recently that models have adequately represented rainfall trends in the Sahel.

One regional difference that some climate models failed to record has been a localised cooling affecting Himalayan glaciers. While many glaciers and ice-fields in the world are shrinking as climate warms, some in the Himalayas are lengthening, partly because of pockets of cooler climate affecting northern India, and partly because of increased snowfall on the mountains.

When the models are run forward to study likely climate change in the future, their predictions about global temperature indicate a range of possibilities. It was being said in 2012 that global average temperature at the end of the century, i.e. in 88 years time, are likely to be between 2 and 6 degrees higher than today.

Such statements, giving a wide range of possible outcomes, reflect proper scientific caution, but leave the consequences very uncertain. If the rise in average temperature were likely to be just 2 degrees, that might seem something that human civilization could survive, though with difficulties for agriculture and water supply in places. However, if a rise of temperature of 6 degrees is really a possibility, that would be much more serious.

Scenarios going beyond climate forecasts

There is an important distinction to be made between results obtained from models which do no more than give estimates of increases in temperature and rainfall, and scenarios which attempt to give a much broader picture of what may happen to food production, water supplies, population movements, and so on. The first kind of forecast produces numbers without drawing out their implications. When experts of various kinds begin to explore implications, they tend to come to greatly varying conclusions.

For example, when it comes to estimating what might happen with a global temperature increase as large as 6 degrees, it is striking that scientists are often more pessimistic than other experts. Examples include Stephen Emmott, who took over the Royal Court Theatre in August 2012 to present his view of how climate change may interact with the expected increase of world population, which he stated as rising towards ten billion by the end of the century.

Other scientific pessimists include Jared Diamond, author of a book entitled simply *Collapse*, and James Lovelock, the originator of Gaia theory, who has said that climate impacts will have such a devastating effect over the next century that we are liable to end up with a much reduced population clinging to refuges in places such as Greenland, plus a few islands such as New Zealand and perhaps even Britain where maritime conditions will moderate the effects of a hotter climate.[1]

I myself have a scientific background and understand very well why many scientists are so pessimistic. But I am also a historian, and a knowledge of history (and prehistory) suggests a wider range of possibilities than the scientists usually consider. History points to instances in the past when human societies have so exploited the environment that they have destroyed most of the resources on which they depended for food. The result has often been that populations collapsed, with numbers sometimes reduced to a fraction of what they had once been, before numbers stabilise and then begin to increase again.

In Britain, it is thought that there have been instances of population collapse in at least three periods — one during the Bronze Age, another after the end of the Roman occupation, and a third following the Black Death in the 14th century.

An example from a different part of the world is medieval Iraq whose grain supplies depended on irrigated agriculture using the waters of the Tigris and Euphrates. From the 8th to the 10th centuries of the common era, there was great prosperity and Baghdad grew to be one of the largest cities in the world. But the irrigated land was being over-exploited, with drainage and fallow periods neglected. There was a build-up of salinity in the soil which greatly reduced crop yields. Cities went into decline and population fell markedly.

In Australia, it is thought that the earliest human population, 50,000 years ago, over-exploited its environment by hunting most large animals to destruction. Some 60 species of animal became extinct, leaving nothing bigger than a kangaroo. There were drastic consequences for vegetation once the animals that had grazed it were removed.[2] Soil fertility deteriorated as recycling of plant nutrients in animal dung diminished, and much less food from wild plants and animals was available for human consumption. Hence population is likely to have declined here also, though it is impossible to say by how much.

But then, people slowly learned from the experience and developed a culture that was more sensitive to its environment, and more successful at living within natural constraints. There were now taboos that forbade killing certain animals, and techniques were developed for controlling rough, unusable vegetation by selective and controlled use of fire. Different patches of scrub and grass were burned off in successive seasons, which had the effect of recycling plant nutrients and promoting fresh growth.

As a historian I tend to the view that patterns of population collapse that have been seen in the past will recur as world population rises from 7 billion at present towards 9 or 10 billion at the end of the century. It will be difficult enough for food production to keep up, especially if major grain-producing areas are afflicted by drought (as has happened in 2012). At the same time, climate change may cause some tropical diseases (such as malaria) to affect people in what are now temperate areas, and new diseases may emerge in response to disturbance of ecosystems.

Alternative technologies

Discussions of "alternative technologies" that might help avoid the worst effects of climate change tend to concentrate on energy supplies, particularly from wind turbines and the sun. But what is also needed is a different approach to agriculture, including better management of soils by farmers and horticulturists. The world's most intensively used crop lands have lost immense amounts of organic matter (humus) from the soil as a result of conventional farming practice which means that an enormous amount of carbon has been transferred from the soil to the atmosphere, contributing significantly to climate change. Much of this damage could be reversed by changes in farming practice.

There are also ways of combining better farming practice with tree-planting through what is known as agroforestry. This is a traditional technique in some parts of the world, particularly in tropical areas, where some crops (e.g. beans and melons) benefit from a degree of shade and protection from the full glare of the sun and can be grown in the shade of trees which may themselves produce a crop of fruit and nuts. Meanwhile plants which do better in more open conditions (e.g. maize) are grown in glades without tree cover.

Agroforestry takes a different form in northern France where farmers' awareness of just how poor their soil had become through over-reliance on chemical fertilizer has led to the establishment of farms where trees are planted in the same fields as grain crops. This is seen as a way of raising levels of carbon in the soil and increasing fertility. Several thousand hectares have been converted to agroforestry recently, with trees planted in rows with wide spaces between to allow farm implements and tractors to pass.

Conclusion

No single approach — no individual green technology — should be regarded as a unique solution to the current environmental crisis. We need a wide diversity of action, including better agriculture, more tree-planting and more sensitive forestry practice. We need improved means of using solar and other renewable energy sources.

Meanwhile, the dangerous experiment that mankind is engaged in with the world environment continues apace, and the next generation (if not this one) will discover what kind of scenario for the effects of climate change is most realistic. One hopes that the remnants of that generation are not holed up in a last refuge on Greenland, but rather, perhaps, enjoying ample food production in agro-forested environments.

Endnotes

1. James Lovelock, *The Revenge of Gaia*, quoted by Tim Flannery, p. 199.
2. Tim Flannery, *Here on Earth*, Penguin edition 2012, pp. 82-3.

THERMODYNAMIC FOOTPRINTS AND LIMITS TO POPULATION

by Andrew R.B. Ferguson

In order to explain the importance of energy to society, in the October 2012 issue of the OPT Journal one of the articles made use of the work of a Canadian scientist, J.R. (Jack) Vallentyne (1926 – 2007). Hopefully it was a fairly lucid exposition, but Paul Chefurka's thoughts, set forth in the last issue of the OPTJ, suggest that it might be helpful to revisit the idea using the slightly different concepts and terminology used by Chefurka.

The basic idea is to avoid using scientific energy units, which many people find difficult. To this end, the basic unit used is the amount of energy used by a person in the form of food. Following Chefurka fairly closely, we name this the Thermodynamic Footprint Unit (TFU). One only needs to divide the maximum energy that could be safely used in the world, in the form of fossil fuel (measured in TFUs), by a specific Thermodynamic Footprint, perhaps one currently applicable within a particular country, to determine the limits to population, *supposing that all were living in that lifestyle*. The Thermodynamic Footprints of people vary enormously, from 5 in India to 79 in the USA.

A maximum Thermodynamic Footprint for the whole world

The maximum Thermodynamic Footprint for the world is determined by the amount of carbon that can safely be released into the atmosphere. At the time of the 1992 Rio conference on climate change, scientists said that to avoid the worst consequences of climate change, the world needed to reduce carbon emissions from burning fossil fuels to within the range 20% to 40% of the 1990 emissions. This sets a limit to the amount of fossil fuel that can be burnt, and hence the energy that humans can safely use. Taking the upper limit of 40%, this amounts to a Thermodynamic Footprint of 38 billion TFUs.

Note that we have been somewhat hopeful in choosing the upper bound of 40%. The world was emitting that amount of carbon back in 1955, yet between 1960 and 1965 the concentration of carbon dioxide in the air *increased*, from 317 part per million (ppm) to 320 ppm. Thus the upper bound of 38 billion TFUs is on the side of danger. Nevertheless, we will use it as a rough guide.

Limits to population

The relationship between Thermodynamic Footprints and the limits to world population is shown in Figure 1. The implications of the graph become clear by looking at the Thermodynamic Footprints of various nations. The Thermodynamic Footprint of the average Indian is only 5 TFUs. If the whole world were to live like an average Indian, then *as far as emissions are concerned*, it would be safe to have a population of 7.7 billion. At the other extreme, the average citizen of the USA has a Thermodynamic Footprint of 79 TFUs. If the whole world were to live like the average American, the safe limit to population would be 470 million, i.e. less that half a billion.

At 36 TFUs per person, the TFUs of the average European comes in between India and the USA. That gives a safe limit to world population of 1.1 billion. So, as has often been reiterated in the OPT Journal, the rate of emissions needs to be greatly reduced below the European level. For our long standing 'Modest European Footprint' we posit an emission rate of only 40% of the current European level, i.e. 14 TFUs. That would give a safe limit to world population of 2.7 billion. Our reason for choosing 40% of the current European level is that, at that rate of energy use, we can surmise — based on Vaclav Smil's work — that a civilization could be maintained, allowing for education and health care.

Some other parameters

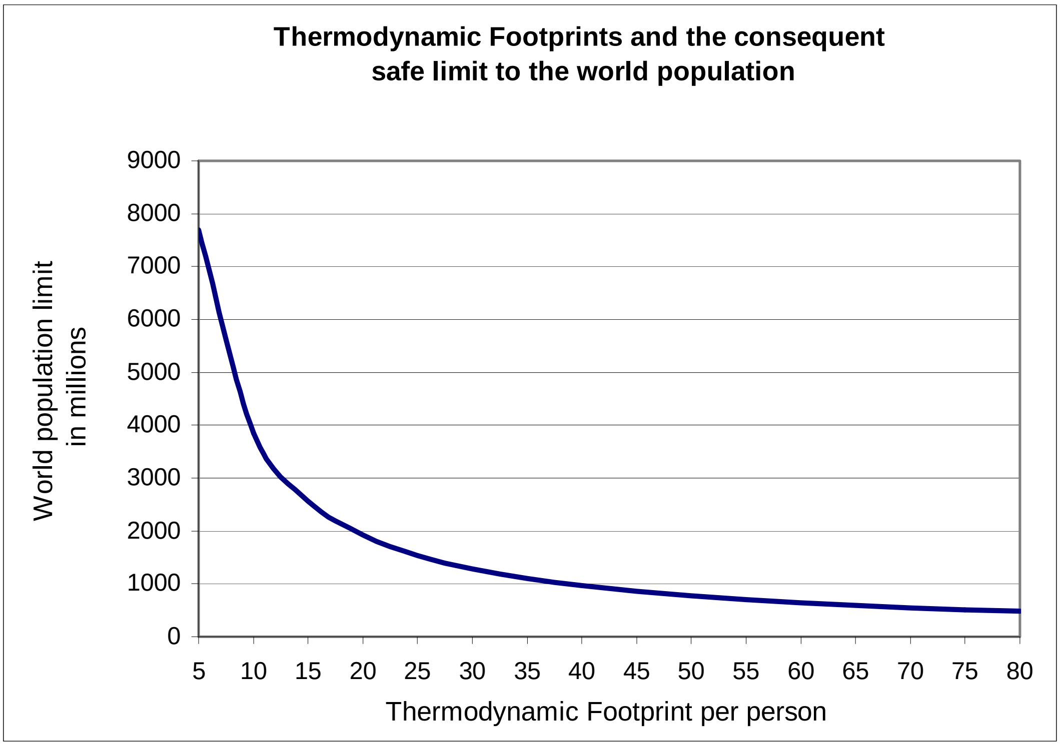
There are other parameters besides carbon emissions which would alter the limit of 2.7 billion that we established for living at 40% of current European emissions. It could be fairly argued that a considerable number of people would be content to live without using any fossil fuels. But that number would be fairly limited. As Chefurka has pointed out, in 1800, when little fossil fuel was being used, there were already signs of ecological damage in the forms of deforestation, desertification and soils ruined by erosion and irrigation.

A *possible* positive is that an increasing proportion of energy can come from renewable sources, meaning that the limit of total energy could be increased. But that is an egg still to be hatched. The nation that has tried hardest to replace fossil fuels with energy from renewable sources is Germany. But so far Germany has only 9% of its energy coming from renewables, and 1.4% of that is from hydro, for which there is little scope for further expansion. It would be unwise to rely on renewables coming to the rescue.

The time available to reduce population

It is fairly probable that by 2075, if not before, even with the recent discovery of the potential of getting oil and gas from fracking, that the availability of fossil fuels will have decreased carbon emissions to force us down to the ‘safe’ limit we have been considering. But 60 years is insufficient time to reduce population to an approximate 2.7 billion living a Modest European lifestyle. However, after that time, unless the renewable energy egg does actually hatch, life will get even more difficult. The only sensible advice is for every nation to reduce its population as far as it can, so as to be ready for the most likely eventuality that by 2075 world population will be far in excess of what can be sustained. Unfortunately humans, like other animals, are more concerned with the present than the future, so appropriate action seems unlikely, but it can do no harm to be aware of what *should* be done.

Figure 1



ECOLOGICAL FOOTPRINTS AND LIMITS TO POPULATION

by Andrew R.B. Ferguson

The previous article — on Thermodynamic Footprints — should be convincing to those who believe in the danger of excessive carbon dioxide in the atmosphere. Doubtless that includes all readers of the OPT Journal, but even as the atmospheric concentration has passed 400 parts per million, there are many people who still deny the danger. It may thus be worthwhile to look at another metric which does not involve carbon emissions. Further explanation is necessary to explain why it does not involve carbon emissions.

The metric is the Ecological Footprint. The essence of the idea is that each person needs a certain amount of cropland, pasture land, forest, and, importantly, land for absorbing the carbon emitted from burning fossil fuels. The last is sometimes described as the 'carbon footprint'. However, although the *idea* is 'land for absorbing carbon', the underlying reality is that it is based on a relationship between energy used and land needed, in other words, the reality is an assumed energy to land ratio. While the Global Footprint Network (GFN) has kept to the concept of carbon absorption, the people there are well aware of the alternative approach. The OPT Journal has been concerned to establish whether the energy to land ratio used by GFN is a good approximation to the energy to land ratio that would be obtained when all energy has to come from renewables. We have continued to work on this over many years. We do take into account that wind turbines take only a small amount of actual land where they are installed, and the fact that photovoltaics may effectively use *no* extra land by being placed on roofs. Taken together this results in a *high* energy to land ratio — that is if wind turbines and photovoltaics could supply all the electrical power. But they cannot, and when account is taken of the need to provide *controllable* electricity, it becomes clear that — at the present stage of development of renewables — the energy to land ratio may not even reach the low one assumed by GFN. Nevertheless we have always assumed, optimistically, that the energy to land ratio that underlies GFN's calculations is a good enough approximation for production of energy from renewable sources.

Land is only *physically* useful for supporting humans if it is fertile. But fertility is very variable. GFN uses several methods to account for different fertilities. The end result permits all land to be measured in the same units — namely 'global hectares'. The whole world has the same number of global hectares of fertile land as when measured in the terms of the standard 10,000 square metres that comprise a hectare. However, individual land, say very fertile cropland, may have several times as many global hectares as it has hectares. A 'global hectare' is essentially a hectare of land of world average productivity.

The foregoing explanation of 'global hectares' has been necessary to make sense of the title of the horizontal axis of Figure 1, **Ecological Footprint in global hectares**, as well as the following amplification and explanation of Figure 1, which serves as a basis for looking at the implications of the average footprint of people in different countries.

The people of India have an average footprint of 0.87 global hectares. That implies a limit to world population of 12 billion. But that figure is misleadingly high, because in the temperate zones, much more energy is required to keep people warm in winter.

China's footprint amounts to 2.13 global hectares per person (the figures all come from 2008 data), which gives a limit to world population of 4.9 billion.

The average footprint in the European Union is 4.71 global hectares, which, assuming that all are living in this lifestyle, implies a limit to world population of 2.2 billion. The difficulty of getting population down to this size in the time available has always been manifest, and from the time of our founder, David Willey, we have posited a 'Modest European Footprint', in which other aspects of life are maintained as nearly as possible, while using only 40% of the energy used in 2001. This reduces the size of the footprint to

3.29 global hectares, and increases the limit to world population to 3.2 billion. Note that the energy assumed for the 'Modest European Footprint' is what is probably needed to provide health care and good education, in other words to maintain a civilized life.

There are some nations, such as Quatar, which have even larger footprints than the USA, but the USA is a significantly large nation with a large footprint — assessed by GFN as 7.19 global hectares per person. That results in a limit to world population of 1.5 billion.

These population figures are considerably higher than the assessment made when using Thermodynamic Footprints. It should first be said that the whole business of assessing Ecological Footprints — including the energy to land ratio related to making use of only renewable energy sources — is liable to substantial error, but with that said, there are other reasons that the Ecological Footprint figures are higher than they should be — besides the one already given for why India's footprint is not applicable to all the world.

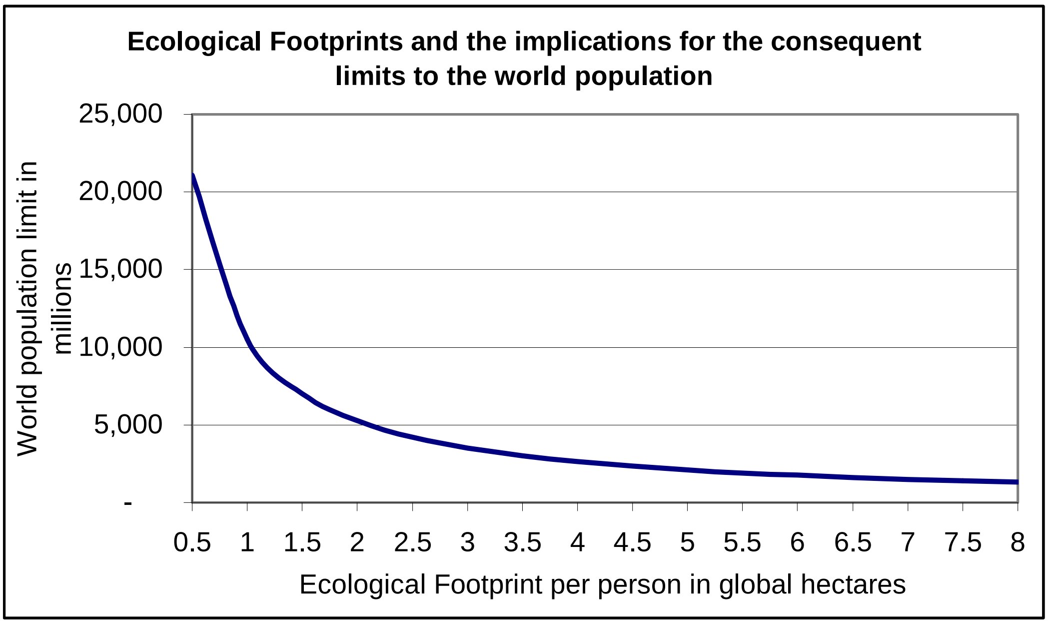
An allowance of only 12% of the available land has been made to preserve biodiversity. Many would argue that is far too low. Then there is the fact that high yields are currently obtained by irrigation and heavy use of fertilizers. Underground aquifers are being drawn down in crucial places, and the making of fertilizers, especially nitrogenous fertilizers, requires a lot more energy when methane is not available as a feedstock to produce the required hydrogen. Many things will become more difficult as we lose the convenience of fossil fuels: Will we be able to sow and harvest at the ideal time? Will we be able to store food for long periods and deliver it when and where it is needed?

There is also loss of land due to desertification. Topsoil is disappearing in places which are important to agriculture, and the fertility of land declines with the loss of topsoil.

With all these additional factors, it becomes clear that even those who don't believe in the dangers of climate change should be aiming for world populations that are in the two to three billion range, with nations having populations based on similar calculations.

There are other possible futures. A breakthrough in capturing and storing energy from renewable sources *might* be made. It *might* turn out that fast neutron reactors will provide an answer to energy shortage for a century to come. But even if the latter looks promising now, on cost grounds it might be impossible to continue to build and maintain fast nuclear reactors when fossil fuels as convenient as oil become scarce. The wisest course of action is to assume that technology will *not* save us, and plan populations accordingly.

Figure 1



THE "BABY BUST" FALLACY

by William B. Dickinson — former head of the **Washington Post Writers Group.** The following is one of his regular letters written for the **Biocentric Institute** of Virginia

I was born 82 years ago into a world of 2 billion people. The planet holds 7.3 billion of us today, and despite lower birth rates we are headed for 9 billion by mid-century. For decades the emphasis by environmentalists has been on “sustainability” — the long-term matching of population with resources. But the overpopulation deniers are back in force. Despite overall increases in population, they say, birthrates are falling in many countries. Soon there will be too few people of working age to fund entitlement programs critical to the growing ranks of the retired. Economic growth will stall. So, more babies, and immigrants, please.

America’s declining birthrate, inaccurately portrayed as a “baby bust” by these alarmists, has inspired fears of falling off a demographic cliff. But the U.S. Census Bureau projects that today’s population of 315 million will top 400 million by mid-century. Young or old, the real problem down the road is likely to be how to create enough middle-class jobs in a fractured society with too many people.

This is not how Jonathan Last of the neoconservative *Weekly Standard* sees it. He has received wide media attention for his focus on the perils of a declining birthrate both in the United States and elsewhere in the world. On a practical level, he argues that soon there won’t be enough young workers to keep the U.S. economy competitive in the world. But Last also spreads the notion that the waning of religion in American life has led to a focus on personal fulfillment rather than on raising a generation to replace us. Unfortunately, President Obama has seized on the demographic cliff scenario to press his case for liberalization of immigration policy. In a March 22 “Fact Sheet on Economics of Immigration Reform,” the White House concluded: “With slowing of population growth, and the aging of the American workforce, America needs more workers.” This will come as news to the many young graduates living in their parents’ basements and unable to find permanent jobs.

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The supposed crisis posed by a rapidly aging population needs a poster child. Japan fits the role because its total population decreased by 259,000 in 2011 and it has the world’s oldest demographics with a median age of 44. But 2011 was the year that Fukushima prefecture was devastated by a record earthquake, with heavy loss of life. And the 0.2 percent decline left Japan with 128 million people crowded onto a land area the size of Montana. For decades, overpopulation deniers have been anticipating economic disaster for a stable and prosperous Japan. Technological innovation and a strong work ethic keep the country on course.

What is one to make of the dour prediction that China, the world’s most populous country at 1.35 billion, faces a stark demographic future unless it abandons its one-child policy and starts producing more babies? Westerners are horrified by the fact that China’s 1971 one-child policy has contributed to 336 million abortions and 196 million sterilizations, many of them forced. But would China's economic resurgence have been possible with an estimated additional 400 million citizens to feed and house?

Although the one-child policy enabled China to enjoy a higher income per head, much of which went into savings and investing, a policy change may be under way. China's new leadership worries that the country's 15- to 24-year-olds will shrink by 38 million, or 21 percent, over the next ten years. In March, the National People's Congress was presented with a proposal that could lead to the eventual phasing out of the one-child and some other population control measures.

Declining populations are anathema not only to rulers who see strength in raw numbers but to business leaders who seek ever bigger global sales. Places like India, where 1.2 billion people jostle for survival, become the promised lands for mass consumption. "India has incredible demographics," Jim O'Neill, outgoing chairman of Goldman Sachs Asset Management, told *WSJ Money* (spring 2013). "It has a very strong birthrate, which means the demographic profile is improving all the time and it is very young. During the next 20 years, the increase…in the working population in India could be as large as the total number of people working in the U.S. today." But author Pankaj Mishbab describes a quite different India, one that produces perilously few nongovernment jobs for millions entering the workforce. "Desperation has grown among educated youth," he wrote (*Wall Street Journal*, March 13, 2013). "Recruitment drives for even menial jobs have been known to cause terrible stampedes and riots."

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Leaders in many poor nations stubbornly embrace the chimera of ever-more babies as the key to national power and influence. In the Middle East, clerics fulminate against "Western plots" to limit the Muslim population through family planning. Pakistan's population of nearly 200 million has risen more than 60 million in the last 15 years, and the average household contains seven people. "The whole country seems absolutely overrun with an increasingly younger population," wrote Irfan Husain in the publication *Dawn*. "Half of us are illiterate. We have water shortages and electricity shortages, and two years ago, after catastrophic floods, we even had a famine. Yet there is no effort to stop our relentless increase."

So great is the fear of economic stasis that even the most prosperous nations feel impelled to add more people. Singapore, a city-state of only 267 square miles, earlier this year announced a $2 billion plan to boost fertility. It later issued a population white paper, "A Sustainable Population for a Dynamic Singapore," that proposes boosting Singapore's population by 30 percent in the next 17 years (after a 32 percent rise since 2000). Population fueled by immigration would grow to as much as 6.9 million, up from 5.3 million today, to ensure a workforce structure of younger people that "can create good jobs and opportunities." Protests, to no avail, came from citizens who cited soaring home prices, infrastructure failings, and the widening gap between the rich and poor in the last decade.

The real demographic cliff in the world, and in the United States, is not posed by too many oldsters and too few young. Rather, the problem is too many *people* to maintain quality of life for all, on a finite Earth where we have failed to live within limits.

GERMANY'S ENERGY GAMBLE by Quirin Schiermeier

An analysis by Andrew Ferguson of the data in the above article in *Nature*

A three page article from the 11 April 2013 issue of *Nature* was kindly sent to me by a former chair of the Optimum Population Trust, Val Stevens. The title of the piece, *Germany's Energy Gamble*, is well chosen. The article contains some thought provoking statistics which are worth dwelling on. I will point out that a deeper probe into costs needs to be made before any conclusions can be drawn as to the possibility of a successful outcome to Germany's *Energiewende*, as the German people call the nation's attempt at making a transition to renewable energy.

Germany is currently investing more than €1.5 billion a year in energy research. This is impressive, though it pales beside the figure for the total amount the Germans are planning to spend on their *Energiewende,* which the article states to be 1 trillion (1000 billion) euros. To get that into perspective, if that sum were to be spent over 40 years and shared between 30 million families, each family would need to contribute €830 each year.

The article lays stress on the potential for using the Sabatier reaction to convert water and carbon dioxide to the gas methane, which is the main constituent of 'natural gas'. In one place, the article lauds the advantages of this Sabatier conversion thus:

> On sunny or breezy days, excess electricity can be used to make methane, which can be stored and then burned to generate power when the winds fail or the days turn dark.

But such generalities need analysing regarding efficiency and costs. The article gives a figure for the efficiency of the conversion process from electricity to methane. That figure is given as "about 50%", which is fairly plausible. The whole process is in two parts, the first being electrolysis of the water to produce hydrogen. That is about 60% efficient. Thus if the Sabatier conversion process is 83% efficient the overall efficiency would be the stated 50%. One does wonder if the implied 83% includes the energy cost of recovering the required carbon dioxide from suitable sources, as well as the more obvious energy costs, which include raising the temperature of the hydrogen and carbon dioxide to the 300–400ºC range that is required to start an efficient Sabatier reaction. But let us accept the 50% figure, as this review aims to illustrate only the *sort of* analysis needed, rather than doing the actual analysis.

Moving on from the generalities that the article presents, let us consider one fairly plausible way of using this system of producing both electricity and methane. We could just deal in percentages, but it may be easier to grasp if we assume some figures for amounts of energy. Thus let us suppose that Germany aims to supply its consumers with 60 gigawatt years, each year, of *electricity* (i.e. a mean 60 gigawatts (GW) — the UK figure is about a mean 45 GW). For the sake of this calculation, let us suppose that so as to satisfy this requirement for energy to be used *directly* in the form of electricity, while also producing extra methane, Germany decides to produce double that amount of electricity, i.e. a mean 120 GW from wind turbines. Assuming a capacity factor of 33%, that means that the wind turbines would need a capacity of 360 GW. Allowing 1.3 euros per watt of capacity[1], that amounts to €470 billion. Including other costs, such as transmission lines, electrolysers, the Sabatier plant, methane storage facilities and gas turbines, it becomes obvious why the previously quoted figure of €1000 billion is as high as it is.

A main reason for producing so much more electricity than is required purely *to satisfy electrical demand* is to overcome the variability of wind turbines. By considerably oversizing the total supply, there is sufficient electricity being generated, for a large part of the time, to satisfy demand *directly*. But even setting the mean electricity generated at twice average demand will not completely solve the problem, as there will be times when it is calm over a large area. For illustrative purposes, let us suppose that 15% of electrical demand still needs to be satisfied by controllable electricity — produced via methane. As we will see, the efficiency of that process adds considerably to the cost. The conversion to methane is about 50% efficient. If we allow that pressurizing the gas for storage is 95% efficient, and that reconversion of the methane to electricity is 40% efficient,[2] the overall efficiency would be 0.5 x 0.95 x 0.40 = 19%. Thus to produce this 15% of the consumer electricity target will require 0.15 / 0.19 = 79% rather than 15%. In other words, an electrical output of 85% + 79% = 164% of the required demand of 60 GW (i.e. 98 GW) will deliver the required mean 60 GW. That is a setback : another way of looking at it is to say that in order to produce the 15% of controllable electricity would require nearly the same number of turbines that are needed to produce the 85% that can be used directly. Without taking into account the cost of the electrolysers, the Sabatier plant, the compressors, and the gas storage facilities, just because of the need for extra wind turbines, the cost of the electricity would be 64% higher than if it could all be supplied directly. When all the additional plant is taken into account, a plausible guesstimate is that to satisfy electrical demand in this way would cost twice as much as it does when producing electricity from wind turbines to supply electricity directly, which is what is being done today.

So producing the electricity looks to be costly, but nevertheless possible to pay for if Germany remains as wealthy as it is today. Next we need to look at the cost of the gas that is produced from the excess electricity.

As noted, converting the electricity to methane is about 50% efficient. Estimating compression efficiency at 95% reduces the efficiency to 48%. Thus the electricity needed is 1 / 0.48 = 2.1 times the energy required from the methane. At current rates of exchange, I pay €cents (€ct) 15.9 per kilowatt hour for my electricity and, allowing for a small standing charge, €ct5.2 per kilowatt hour for my natural gas. Thus as a preliminary estimate, we can say that to buy methane that was produced from electricity would cost in the region of €ct15.9 x 2.1 = €ct33 per kilowatt hour (kWh). And that is 33 / 5.2 = 6 times as expensive as buying natural gas. But that has not taken into account our previous estimate that electricity would cost twice as much as today. Taking that into account, natural gas would cost in the region of €ct66 per kWh, 13 times as much as today.

The point could be made that it would be more appropriate to start with the wholesale price of electricity and compare that to the wholesale price of gas. That is probably true, but it is also true that an accurate analysis would be even more complicated. A main reason for storing the methane is that by producing it we can mop up the ‘unwanted’ electricity from the wind turbines. But that electrical input will not be steady. At times it will make use of all the electrolysers and the Sabatier conversion plant. But at times of low wind, all that plant will be close to idle. Thus a significant part of the cost will come in poorly utilised plant and workers.

Another hope of the renewable energy optimists is that the gas produced by the Sabatier reaction could be used to power vehicles. A litre of petrol (gasoline) contains about 9 kWh of energy. With the caveat that the above calculations may be somewhat misleading, the cost of replacing a litre of petrol with the equivalent energy from gas made by the Sabatier reaction would be €ct66 x 9 = €ct590. In the UK we currently pay about €ct165 per litre of petrol — but most of that is tax. The government might decide not to tax gas, but they would then have to find something else to tax to replace the tax currently taken from petrol.

These options are expensive, and then there is the feedback factor: when *energy* is more expensive, *everything* is more expensive, so people are poorer. A price which seems bearable now is likely to become available only to the wealthy when most people are poor.

It will have been noticed that I have referred exclusively to electricity from wind turbines. Doing that put the best face on this analysis. A telling statistic in the article under review is this:

> Renewable-power producers cashed in an estimated €20 billion last year for electricity that was actually worth a mere €3 billion on the wholesale electricity market. The difference came out of the pockets of consumers.

It may seem surprising that wholesale electricity from renewables is being supplied at nearly seven times the cost of the same amount of electricity from fossil fuels, but the energy from photovoltaics is very expensive, as is apparent from the large subsidy that has to be paid to support it.[3] I think Germany is likely to regret the expense of having installed so much photovoltaic power, which anyhow has other disadvantages.[4] Whether that proves to be the case or not, I have not loaded the above analysis with the egregious costs that would emerge from incorporating the cost of electricity from photovoltaics.

According to a graph in *New Scientist*,[5] Germany is currently producing about 7.6% of its total energy requirements from non-hydro-renewables, with a further 1.4% coming from hydro, to make a total for renewables of 9%. There is certainly a long way to go. The article finishes by quoting from Eberhard Umbach, president of the Karlsruhe Institute of Technology, who oversees the €500 million a year put into Germany's national energy research activities. He is convinced that Germany is the right place to conduct the experiment, saying, "If it fails it will be bad for Germany, but if it succeeds the whole world will profit." One cannot demur from that, and we should be grateful to the Germans for their courage, but at this stage, we should not make the assumption that their gamble will succeed and prove transferable to the rest of the world.

Endnotes

1. http://www.windustry.org/resources/how-much-do-wind-turbines-cost (29.3.13): "The costs for a utility scale wind turbine in 2012 range from about $1.3 million to $2.2 million per MW of nameplate capacity installed." The midpoint is thus about $1.7 per watt, or 1.7 / 1.52 x 1.17 = €1.3 per watt.
2. Under the right conditions — that is running steadily to provide a base load — combined cycle gas turbines can operate at 50% efficiency, but when they have to vary their output, which is likely to often be the case when used to balance varying wind inputs, 40% efficiency is probably a fair estimate.
3. Wikipedia: "As of February 2012, feed-in tariffs range from 3.4 ct/kWh (4.5 ¢/kWh) for hydropower facilities over 50 MW, to 24.43 ct/kWh (32 ¢/kWh) for solar installations on buildings up to 30 kW. In 2012, the tariff for new solar installations dropped to 18.36 ct/kWh (24 ¢/kWh) subsidies for PV."
4. Cost is still a major problem with photovoltaics (PV). However, PV has a problem which is not amenable to solution, namely its low capacity factor. The capacity factor is the amount of electricity that is actually produced as a fraction of that which would be produced were the PV panels producing at full capacity all the time. At midday, the PV panels can be producing at full capacity (as assessed in the laboratory) or even surpassing it. In Germany, the capacity factor is about 10%. There is no imaginable way that can be improved, because it is related to the ratio between the intensity of the sun at midday on a sunny day and the average insolation over the year. Thus, for example, if one were to install PV panels such that at midday on a sunny day they produce *twice* the average demand for electricity, because of the 10% capacity factor, they would provide only 2 x 0.10 = 20% of the average demand for electricity. The other 80% would have to be provided by controllable inputs. Also the output of PV varies enormously from hour to hour. This produces great problems for the grid, requiring a lot of highly controllable electrical input to balance the variations in the contributions from PV.
5. *New Scientist* 27 April 2013, *Germany's Green Revolution* (pp.52-53).