# OPTIMUM POPULATION TRUST JOURNAL APRIL 2003

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The development of the global economy, which has been institutionalized with the signing of the GATT Uruguay Round and the setting up of the WTO will, we were assured, usher in an era of unprecedented prosperity of all. However, as the contributors to this book have sought to show, this assertion is based on no serious considerations of any kind. On the contrary, it can only lead for most of humanity to an unprecedented increase in general insecurity, unemployment, poverty, disease, malnutrition and environmental disruption.

Edward Goldsmith in Chapter 6, p. 296, of *The Case Against the Global Economy & for a Turn Towards Localization*, edited by Edward Goldsmith and Jerry Mander

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## INTRODUCTION

As usual, this introduction is in part an Abstract of what follows. The last issue finished with a brief study of wind/biomass energy, but its scope was limited, taking into account only the implications of the fact that it is hard for the operators of wind turbines to guarantee a specified output even four and a half hours ahead. In this issue (pages 3-10) the analysis is extended to cover longer term variations. Again the assumption is that, in a renewable energy situation, only biomass can provide a time-independent back-up.

The US and the UK are given as two prime examples of the general wind/biomass problem. Were the USA to develop all its wind resources, the related composite wind/biomass system would cost about $700 billion, and it would provide at most 18% of *primary energy* (enough to satisfy 16 years of population growth). The biomass-fired generating stations would require a somewhat improbable 180 million hectares of land.

With respect to the UK, providing 22% of its *electricity* from a wind/biomass system would require 32% of the UK's ecologically productive land — that is certainly not available. Of course the UK was bound to be a more hopeless case because of its greater overshoot of biocapacity.

On pages 11-15, we take a look at the implications of a United States Department of Agriculture study of using corn to produce ethanol. The conclusions can be briefly stated:

1. Overall, ethanol increases atmospheric pollution. But when ethanol is being produced as a gasoline *enhancer*, to reduce *tail pipe* emissions, no clear boundary can be set at which the energy efficiency of ethanol production becomes unacceptable.
2. The amount of energy produced — as *useful* energy in liquid form — is so small in relation to the area of land needed to produce it, that the production of ethanol as a gasoline *extender* cannot be justified, especially in view of the associated environmental damage.

Edmund Davey probes the previous piece with some incisive questions; then a few short pieces follow, before reprinting *The Social And Ecological Consequences of Globalization*, pages 23-25. This was distributed, in September 2000, with *The Pherologist*, but perhaps it is particularly appropriate to publish it again in this issue, as it has some bearing on the *2nd Footprint forum*, *Part II*, which will be the main feature of the October issue of this journal.

Also relevant to the next part of the *2nd Footprint forum*, Edmund Davey resumes his incisive questions, with *A Plain Man's Questions Concerning Eco-footprinting* (pages 26-29).

Last, but by no means least, is a piece by Jill Curnow, Vice-President of the New South Wales branch of *Sustainable Population Australia*. She reviews the book by Professor (of Statistics) Bjorn Lomborg, *The Skeptical Environmentalist*. As David Hume observed long ago, it is those with the loudest trumpets (and these days with the best publicity machine), who tend to win the argument. Bjorn Lomborg was bringing a message that almost everyone was delighted to hear. He seemed set to follow in the footsteps of the ever-popular late Professor (of Marketing) Julian Simon, and waste the time of a lot of good scientists. Perhaps his success is not assured, because since Jill wrote her piece, Lomborg has been so thoroughly trounced by the entire academic establishment that he may sink without trace! Nevertheless, we are lucky to have Jill's analysis (pages 30-33) — delivered with a light and amusing touch — describing the methods by which such people manage to confound reality.

Thanks are due to Edmund Davey, Rosamund McDougall, and especially to Yvette Willey, whose careful proof reading picked up many a slip.

## WIND/BIOMASS ENERGY CAPTURE: AN UPDATE

by Andrew Ferguson

**Abstract.** Wind energy suffers from *short term* unpredictability, giving problems of integrating the output with a time-independent source. Moreover, *long term* variability means that a substantial proportion of the energy required to satisfy consumer demand must come from a time-independent source (in the context of renewable energy this means biomass). We also see that wind energy can have only a small effect in raising net energy-capture from the mean figure of 1.5 kW/ha, available from the whole biomass spectrum, up to the figure of 3 kW/ha which is assumed for eco-footprinting. The importance of a realistic assessment of net energy-capture is apparent from the fact that biomass alone could support only a fraction of the present population.

It is demonstrated that if the USA develops all its wind resources, the related composite wind/biomass system would cost about $700 billion, and would provide at most 18% of *primary energy* (enough to satisfy 16 years of population growth). Fuel for the biomass-fired generating stations would require 180 million hectares of land (not likely to be available). In Britain, to provide 22% of national *electricity* from a wind/biomass system would require 33% of the UK's ecologically productive land: an amount that is certainly not available.

The precursor to this article, pages 38-40 of the October 2002 issue of the *OPT Journal*, was not a complete analysis, since it took into account only the short term variability of wind. This update extends the analysis to cover long term variability. It has been made possible because Morten Lintrup, of the Danish carrying capacity organization DROS, kindly sent me wind data taken from eight issues of the admirable *WindsStats* newsletters (see Table 1).

In order to make this paper complete in itself, some of the text from the preceding article is repeated. In following in the path of that article, we also aim to keep wind power within the wider perspective of all types of renewable energy.

Capacity factor means 'production as a proportion of rated output'. At the time of writing the previous article, the only annual national capacity factor figure I had available was 25% for the UK. The UK appears to be well situated to catch Atlantic winds, so I was not sure that this figure would be representative. It is possible to be more confident about the four nations shown in Table 1, Denmark, Germany, the Netherlands and Sweden. As it happens, the difference in capacity factors is not great: over the two years of Table 1, these four nations achieved a mean capacity factor of 22%.

The October 2002 issue of the *OPT Journal* (pp. 33-37) showed that photovoltaics cannot play a significant part in the quest for renewable energy because of expense. The April 2002 issue, pp. 11-13, showed that the problem with wind power is that it is limited in scope. Later we will consider the ramifications of this limited scope, but first we will focus on the implications of the short and long term variability of wind strength, and its effect on land requirements.

Table 1 shows that there are some months of the year when the capacity factor drops to low levels, for example below 8% for Germany and the Netherlands in August 2000. Not apparent from the table, but common knowledge, is the variation in wind strength

Table 1 shows "Monthly and hence yearly, capacity factors from Wind Stats newsletter, October-98—Sept-99"

Table 2 shows "Monthly and hence yearly, capacity factors from Wind Stats newsletter, October-99—Sept-2000"

Both appear together on page 4, in landscape orientation (which cannot be duplicated on screen). Download by right-clicking on icon (when in in Print Layout or Print Preview (edit) mode), and then choose Worksheet Object — Open, to see the whole spreadsheet. The segment that appears in the printed publication extends from cell A1 to cell Q40. The file is of the Excel 4 type (34 kb).

Microsoft Excel
Worksheet

which occurs from one day to another, or one week to another. While the monthly variability shown in the table provides an interesting background, and illustrates the imperative need for back-up, what chiefly concerns us, in this analysis, is the mean capacity factor achieved for all four nations over two years. That figure, as already mentioned, and as shown at the bottom right of Table 1, is 22%.

Now we can address the question of how to run a composite wind/biomass energy system to satisfy normal consumer demand. Let us, by way of an example, consider a system using wind turbines with a rated capacity of 100 $MW_e$ (megawatts of electrical power). At the aforementioned mean capacity factor of 22%, this would produce 22 $MW_e$. But not quite all this 22 $MW_e$ could be utilized, because those running the system would need to have some warning of what to expect from the wind system, within the next few hours, to allow time to adjust the output from the time-independent (biomass) power plants.

Some clues on the importance of this short term variability came from an article by science editor, Peter Bunyard, in *The Ecologist*, April 2002, pages 51-53. He told us that, in 2001, the UK energy department produced a new energy trading arrangement (NETA). This demands that the wind power generator should predict, four and a half hours in advance, the exact amount of electricity that is to be produced. Financial penalties apply for getting the figure wrong. We have a clear indication of how difficult the wind power operators found it to make predictions four and a half hours in advance, because output to the distributors fell by 14% as a direct consequence of NETA. We can thus expect that of the 22 $MW_e$ which the wind turbines would generate, 14% would be lost due to the unpredictable nature of the supply. This reduces the usable power output to 18.9 $MW_e$.

The biomass-fired power plants would make up the difference, in order to satisfy consumer demand. But where should we set the limit of demand that the composite system should cover? Over a fairly extensive system of wind turbines, it is unlikely that all of them will, at the same time, be running close to their full rated output. Thus, trying not to overstate the problems for wind, we might assume that the *maximum* output from the entire turbine system would be only 80% of the rated capacity of the wind section. Later we will consider the effects of varying this assumption.

So we need to design a composite system which will deliver 80 $MW_e$. On occasions this might be delivered entirely by the wind turbines, and on other occasions by a time-independent back-up system (biomass being the only plausible renewable energy source).

As with any conventional power station, the electricity which is actually delivered from the system is never the full capacity of the system, because of the variability of consumer demand. A coal-fired power station operates in the region of 60% capacity. Thus even though, as explained, the system would be capable of developing 80 $MW_e$ to satisfy peak demand, over the year we would expect this mooted composite system to actually deliver about 0.60 x 80 = 48 $MW_e$. Since the wind would deliver a usable 18.9 $MW_e$, this leaves 29.1 $MW_e$ to be supplied by the biomass-fired power plant. Using 33% as the conversion efficiency, heat to electricity, this would require 29.1 / 0.33 = 88 $MW_{th}$ of biomass energy.[1]

It is generally agreed that a sustainable yield of biomass, over large areas, averages 3 dry t/ha/yr, which approximates to 60 GJ/ha/yr, or 2 $kW_{th}$/ha. This means that supplying the 88 $MW_{th}$ would require 44,000 hectares.

Because wind turbines, including the required access roads, actually occupy only a small area (about 2-5% of the area over which the turbines are deployed), their energy-capture is high. In terms of primary energy equivalent, 1100 $kW_{th}$/ha is a sound estimate. Additionally, a proportion of the wind turbines would be situated off-shore, or on land that was not biologically productive. Thus — accurately enough for our purposes — we may put the energy-capture of wind turbines as high as 3000 $kW_{th}$/ha of productive land required. This means that the wind turbines would *monopolize* 19 hectares of productive land.[2]

We now have the data to calculate the energy-capture of the composite system. In primary energy terms, the total power output of 48 $MW_e$ is 145 $MW_{th}$.[3] Dividing this by the biologically productive land required, 44,019 ha, gives an energy-capture of 3.30 $kW_{th}$/ha.[4]

It is evident why we did not need to be too careful with our estimate of the energy-capture of wind itself: had we guesstimated 4000 $kW_{th}$/ha, instead of 3000, 14 hectares would have been required for the turbines instead of 19 — with a negligible overall effect.[5]

Since this 3.30 kW/ha is only marginally above the 3 kW/ha assumed for eco-footprinting (OPT 2/2, October, p. 2), it is going to have only a small effect on raising the mean up to 3 kW/ha, from the 1.5 $kW_{th}$/ha which is the rough estimate of the energy-capture available from biomass (some of which needs to be used to produce energy in liquid form, as explained on page 17 of the *OPT Journal*, October 2002). Later we will see exactly how much effect the composite wind system has on mean net energy-capture.

**Generalising the analysis**

Having followed through the example of a wind system rated at 100 $MW_e$, which contributes, on average, 22 $MW_e$, when integrated into a composite system that is capable of delivering 80 $MW_e$, we can set the matter out in general terms, relating everything to the output of the turbines, which we might designate 'T' (with a value of 22 $MW_e$ in this example).

The rated capacity of the turbines would, of course, be 1 / 0.22 = 4.55 times T. The composite system should be designed for a peak production of 3.64 times T. With our assumption of operation at 60% capacity factor, the composite system would *actually produce* 2.18 times T. Since 86% of the output T is usable, the wind turbines *usefully* supply 0.86 times T. This leaves the biomass component to supply 1.32 times T.[6] Those factors can, of course, be checked in the previous example by using them to multiply the assumed value of T, 22 $MW_e$.

**The situation in the United States of America**

It will be recalled (*OPT Journal*, October 2002, p. 17) that the chief limitation on wind power in the U.S. was that if the full wind potential were to be exploited, producing 777 billion kWh/yr, this would still only replace 8% of U.S. primary energy demand (or more like 6.5% if allowance is made for inputs). We can now alter that picture to contemplate a composite system able to accommodate variations in consumer demand.

777 billion $kWh_e$/yr, or 89 million $kW_e$, is the output from the turbines. The amount that a composite system would produce, that is one properly integrated with this turbine output, is 2.18 x 89 = 194 million $kW_e$. At our calculated 3.3 kW/ha, the ecologically productive land required for this composite system would be (194 / 0.33) / 3.3 = 180 Mha.[7]

180 Mha is hardly feasible, since the U.S. has, depending on definition, 500 - 740 Mha of biologically productive land, a large proportion of which is in use. Moreover, in a renewable energy situation a lot of land would be required to supply biomass for direct heating.

Of equal note is the fact that the *amount* of energy captured by the composite wind/biomass system that we are envisaging is not going to contribute *a large part* of the total energy demand. To put figures on it, the composite system would produce 2.18 x 89 million

$kW_e$ = 194 million $kW_e$. That is about 50% of the total electricity consumed in the United States.[8] While 50% of electricity may seem encouraging, the energy captured is not large within the overall picture of energy demand. Converted to primary energy terms, the 194 million $kW_e$ represents about 18% of the total energy used in the U.S.. Rate of energy growth in the U.S. exceeds population growth, *but even ignoring that fact*, 16 years of population growth would suffice to cancel out the huge effort of deploying about 400,000 1 MW turbines, building 3200 biomass-fired power plants each with a capacity of 100 MW , and using 180 Mha of land to supply them. Since the total cost of building the composite system would be in the region of 700 billion dollars, it must be doubtful if it would be completed before being overtaken by population growth.[9]

The implications of the preceding paragraph are so stark that it is only incidental to the analysis — but nevertheless we should not lose sight of the fact — that a substantial part, perhaps a fifth, of the output of the turbines would be needed as input to build and maintain them. One of the problems of developing a large wind system is that, for many years, the input is greater than the output.

Thus a *composite system based on wind power* is only going to contribute 18%, at most, to the whole of U.S. energy demand; and its output seems unlikely to keep pace with 16 years of population growth. Moreover, there is little else, amongst renewables, of sufficient magnitude, and with a high enough energy-capture, to make a significant contribution.

As has already been observed (see page 17 of the October 2002 *OPT Journal*), the mean energy-capture that can be achieved when providing heat and liquid fuels, from renewable sources, is unlikely to exceed 1.5 kWh. Now we can take a representative sample of the whole energy supply, this time of say 1000 $kW_{th}$. Of this, let us *hope* (for we have ignored the inputs) that 18%, 180 $kW_{th}$, would come from wind/biomass. It would require 180 / 3.3 = 54.5 ha, while the remaining 82%, 820 kW, would require 820 / 1.5 = 546.7 ha. Thus, overall, energy-capture would be 1000 / 601 = 1.66 kW/ha. In other words, our wind/biomass energy system would have raised the mean energy-capture figure, from 1.5 kW/ha, by only 0.16 kW/ha.

This result makes it clear why, in order to reach eco-footprinting's assumed energy/land ratio of 3 kW/ha, it will probably be necessary to assume *some* input from fossil fuels (probably mainly coal), with perhaps some contribution from tar sands and shale. It is only on that basis, that the 3 kW/ha figure can be honestly defended as coming within a description of being 'not excessively optimistic'.

**Sensitivity to varying the parameters**

There is room for doubting some of the parameters used above. Let us vary them slightly to see how sensitive the final result is to such variation. Suppose that the U.S. mean capacity factor were to be 25% instead of 22%. This would raise the composite energy-capture from 3.3 kW/ha to 3.6 kW/ha. Suppose *additionally* that instead of 14% of the output of the turbines being lost due to short term variability, that figure could be reduced to 7%. That would raise the composite energy-capture to 3.9 kW/ha. Suppose, *additionally*, that the wind turbine system never produces more than 70% of its rated capacity, so that we only need a composite system capable of producing 70% of the rated capacity of the wind turbines, instead of 80%. This would raise the composite energy-capture to 4.5 kW/ha.[10] Keeping to our approximation that the composite system would produce about 18% of total energy, this 4.5 kW/ha would raise the mean energy-capture from 1.5 kW/ha to 1.70 kW/ha — a hardly significant improvement over the previous figure of 1.66 kW/ha. In conclusion, the result is not sensitive to reasonable changes in the parameters.

**A lesson from a wind project in northern Britain.**

Peter Bunyard mentioned plans for the "world's largest wind farm, with a capacity of 600 MW, on the Isle of Lewis," adding that this "one project alone would meet nearly 0.5 per cent of the UK's electricity needs." The figure seems encouraging, perhaps suggesting the thought that were this project to be repeated 20 times, it would provide 10% of the UK's electricity needs. However, from our previous considerations, this amount of energy from wind turbines would require a composite system which would actually deliver 2.18 x 10% = 22% of the UK electricity. The total area of biologically productive land needed to produce that amount (satisfying consumer demand as required) would be 6.7 million hectares.[11]

That area constitutes 33% of the UK's biologically productive land, and is a ludicrous figure in the context of the UK's present population and its wood production.[12] Although the UK is gradually increasing the amount of timber grown at home, a peak is expected around 2025. By that time, the UK will be producing a *third* to a *half* of its present wood consumption; moreover UK citizens are not presently burning much wood for heating — they are merely using it for products of various kinds.

On page 103 of *Tomorrow's World*,[13] Duncan McLaren and his co-authors said that 190 billion kWh/yr was their "optimistic" estimate for electricity from wind power in the UK by 2050. Perhaps it would be wise to apply a reality check to that figure before considering the land implications, in the context of a fossil-fuel-free society.

The UK has a land area which is 2.6% of that of the United States. The American Wind Energy Association estimate a potential wind output of 675 billion kWh/yr for onshore turbines. Thus on the basis of land area, the UK might get 18 billion kWh/yr. High in thrall to optimism, we can pass over the fact that difficulties may arise from the UK being far more built-up than the US.

Off-shore is more difficult, but the UK has a coastline of roughly 2000 km compared to 6000 km for the US. On that basis, the UK should, pro-rata, be able to get a third of the estimated offshore potential of 102 billion kWh/yr of the US. That makes a total of 52 billion. Thus, leaving a margin for error, 65 billion kWh/yr would seem a better figure, in order to keep optimism within bounds! So how much land would be needed to supply 65 billion kWh/yr from wind/biomass? 65 billion kWh/yr is 22% of the UK's electrical supply, and we have already seen that that would require 33% of the UK's ecologically productive land.

## Implications

Drawing data from a wider canvas than this paper, we should note that the *really intractable* problem of renewables lies in changing current sunshine into '*liquid* sunshine'. Despite the problems demonstrated here, producing electricity is the *easier* task. The USA and the UK serve as examples from which the following general conclusions can be drawn. It is hard to capture 'current sunlight' in quantities which — in relation to the amounts of energy used by modern civilization — are significant. Thus the present human population of six billion has to be seen as a temporary bubble, made possible by relatively easily access — over the past century or so — to 'ancient sunlight'. So what can be done?

It would be unreasonable to anticipate that all nations will become aware of what the future holds soon enough to take appropriate action. It is, however, possible that some might both see and act. Europe's indigenous population would contract without net immigration.[14] In the United States, about seventy percent of the population expansion is the result of net immigration. With balanced migration, and a small change in popular mood, the US could achieve the same downward trend in population that Europe would be able to achieve with balanced migration. Thus both Europe and America *could*, by taking appropriate action, go some way toward getting their populations in line with sustainable use of biocapacity.

It is hard to exaggerate the importance of getting this message across, especially in view of the almost boundless optimism about renewable energy which emanates from various environmental 'experts', who almost unanimously present wind energy as a sovereign remedy for an energy-hungry world. The truth is, whether we look at wind alone or the whole scene of renewable energy, fulfilment of our hopes for a tolerable future for the human race must depend upon achieving a smaller population.

## Endnotes

1. 29.08 $MW_e$ = 29.08 / 0.33 = 88.12 $MW_{th}$.
2. 18.92 $MW_e$= 18,920 / 0.33 = 57,333 $kW_{th}$
   At 3000 $kW_{th}$/ha this requires 57,333 / 3000 = 19.11 ha.
3. 48,000 $kW_e$= 48,000 / 0.33 = 145,455 $kW_{th}$ (Note that, for general statistics, the output of hydro and nuclear plants is expressed as the amount of primary energy that would be required, used in conventional power plants, to generate the output of hydro and nuclear plants).
4. Composite energy-capture 145,455 $kW_{th}$/ (44,060 + 19) = 3.2999 $kW_{th}$ha.
5. At 4000 $kW_{th}$/ha, land monopolized by turbines would be 57,333 / 4000 = 14.33 ha.
6. Let Raw turbine output be T (i.e. amount actually generated).
   With a 22% capacity factor, the rated capacity of the turbines would be (1 / 0.22) T = **4.545** T.
   The composite system would be designed for a peak production of 80% of this, that is (1 / 0.22) x 0.80 T = **3.636** T.
   Operating at 60% capacity factor, the system would actually produce 3.636 x 0.60 T = **2.182** T.
   With 14% of output wasted, due to short term variability, usable output from turbines = T x 0.86.
   Since the wind turbines supply 0.86 T, biomass supplies 2.182 - 0.86 = **1.322** T.
7. 777 x $10^9$ $kWh_e$/yr = 777 x $10^9$ / (24 x 365) = 88.70 x $10^6$ $kW_e$
   Using the parameter 2.182 of previous endnote.
   The amount of electrical power produced by a composite system able to handle this output from the turbines, would be 2.182 x 88.70 x $10^6$ $kW_e$ = 193.54 x $10^6$ $kW_e$
   The thermal equivalent of this is 193.54 x $10^6$ / 0.33 = 586.49 x $10^6$ $kW_e$.
   At 3.30 $kW_{th}$ /ha the ecologically productive land needed is 586.49 x $10^6$ / 3.30 = 177.7 x $10^6$ ha.

Slightly more long-winded, but perhaps more transparent, is to calculate the areas individually.
The output of 777 x $10^9$ $kWh_e$/yr = 777 x $10^9$ / (24 x 365) = 88.70 x $10^6$ $kW_e$ = 88.70 / 0.33 = 268.78 x $10^6$ $kW_{th}$.
At 3000 $kW_{th}$/ha, this requires 268.78 x $10^6$ / 3000 = 89,595 ha = 0.09 Mha.
Using the parameter **1.3218** of previous endnote:
The biomass output supply required would be 1.3218 x 88.70 x $10^6$ $kW_e$ = 117.24 x $10^6$ $kW_e$.
The thermal equivalent of 117.24 x $10^6$ $kW_e$ = 117.24 x $10^6$ / 0.33 = 355.28 x $10^6$ $kW_{th}$.
At 2 $kW_{th}$/ha, this requires 355.28 x $10^6$ / 2 = 177.64 x $10^6$ ha.
Thus the composite area of ecologically productive land required = 177.64 x $10^6$ + 0.09 x $10^6$ = 177.7 Mha

8. In the year 2000, US electricity consumption was about 3.5 x $10^{12}$ $kWh_e$/yr.
194 x $10^6$ $kW_e$ = 194 x $10^6$ x (24 x 365) = 1.70 x $10^{12}$ $kWh_e$/yr.
This is 1.70 / 3.5 = 49% of the total electricity supply.

9. With a 22% capacity factor, the rated capacity of the turbines would be (1 / 0.22) T = 4.545 T; so the rated capacity of a system capable of producing 777 x $10^9$ kWh/yr is:
(777 x $10^9$ x 1000 / (24 x 365)) x 4.545 = $\underline{\underline{403.1}}$ x $10^9$ W (or 403,100 turbines each of 1 MW).
The capital cost of turbines is about US$1 per watt of rated output, so cost would be $403 billion.
The composite system would be designed for a peak production of 80% of the rated power of the turbines, that is **3.636** T (see endnote 6).
Since the backup must at times produce nearly all the power, the backup must be able to provide:
(777 x $10^9$ x 1000 / (24 x 365)) x 3.636 = $\underline{\underline{322.5}}$ x $10^9$ W (this checks since 322.5 is 80% of 403.1).
The capital cost of a conventional power plant is again about US$1 per watt of rated output, so cost would be 322 billion dollars. (Note that 100 MW would be fairly large for a biomass powered plant, and 322,000 MW would probably indicate 3220 plants each of 100 MW capacity).
Thus total cost of the composite system would be 403 + 322 = 725 billion US dollars.
That the output is about 18% of current U.S. total energy use is estimated as follows:
In 2000, U.S. energy use (estimated from 1995 data) = 93.97 [quads] x $1.0112^5$ = 99 quads = 99 x 1.055 x $10^{18}$ = 104.8 x $10^{18}$ J, or 104.8 EJ.
Primary energy required to generate 193.54 x $10^6$ $kW_e$ (see endnote 6 = 193.54 x $10^6$ x (24 x 365) / 0.33 = 5.138 x $10^{12}$ $kWh_{th}$ = 5.138 x $10^{12}$ x 3.6 x $10^6$ = 18.5 x $10^{18}$ J or 18.5 EJ.
So wind could replace 18.5 / 104.8 = 17.7% (say 18%) of the total energy use.
The DOE reported a nearly 40% increase in energy between 1970 and 2000, making an annual growth rate of 1.127%, say 1.12%
However, ignoring that, growth of population alone, at the rate of the three closing decades of the last century, 1.06% per year, would increase demand over 16 years by $1.0106^{16}$ -1 = 18.4%

10. As well as the calculations shown above, the logic was followed through on a spreadsheet, thus making it easy to vary the parameters.

11. Using the parameter **2.182** (see endnote 6), the composite system which would make use of this raw output of 10% of UK electricity from wind turbines would be a system which would actually deliver 2.182 x 10% = 21.8% of UK electricity.
UK's electrical consumption is about 295 billion kWh/yr.
21.8% of this is 0.218 x 295 = 64.31 billion kWh/yr = 64.31 x $10^9$ / (24 x 365) = 7.34 x $10^6$ kW.
The primary energy equivalent is 7.34 x $10^6$ / 0.33 = 22.2 x $10^6$ $kW_{th}$.
Thus at 3.30 kW/ha, the biologically productive land required = 22.2 x $10^6$ / 3.3 = 6.74 Mha.

12. According to the spreadsheet for *Ecological Footprints of Nations*, the UK has 20.3 Mha of ecologically productive land, thus 6.74 Mha is 6.74 / 20.3 = 33%.

13. McLaren, D., S. Bullock, Y. Nusrat. 1997. *Tomorrow's World*. London: Earthscan.

14. Data from PRB 2002 data sheet: whole of Europe, 7.26 M births, 8.15 M deaths per year.

## IMPLICATIONS OF THE USDA 2002 UPDATE ON ETHANOL FROM CORN

by Andrew Ferguson

Without doubt, there are workers in the field who would challenge some of the data used in the USDA's report, *The Energy Balance of Corn Ethanol: An Update*.[1] However, it is admirably comprehensive. It includes data from nine previous reports, and it uses them to guide its own judgements; so the best course of action would seem to be to accept the figures emanating from this USDA update, and enquire only about the implications. These are summarized in the final section.

First, we should note that ethanol has two possible functions. One of them is as a gasoline *enhancer*, that is to make gasoline burn more efficiently, producing less noxious gases. For this purpose, since no definite value can be ascribed to living in a smog free and healthy environment, no clear boundary can be set at which the energy efficiency of ethanol production becomes unacceptable. However, we should note that it seems likely that *overall*, using ethanol increases *atmospheric* pollution, as is fairly obvious from Shapouri et al.'s calculation (2002, p. 10) of an energy ratio of 1.34. This means that for each 100 units of ethanol emissions coming out of the tail pipe, a further 75 units are burnt 'off-scene'. In fact the balance of the evidence at present appears to be that ethanol increases even tailpipe emissions, but as the use of ethanol as a gasoline *enhancer* is not germane to this analysis, further points on that aspect are relegated to endnote 2.

The other mooted function of ethanol is as a gasoline *extender*, that is to reduce the amount of gasoline that has to be used. It is this second function which has a reasonably clear boundary, and is the subject of this paper.

In order to be able to see the underlying energy efficiency more clearly, we will consider ethanol being used by itself to power vehicles (rather than as a gasoline extender), even though using undiluted ethanol may be unlikely to happen on a large scale.

The report's Table 1 uses an average corn yield of 125 bushels/acre = 308.7 bu/ha.

The corn to ethanol conversion rate is shown in the same table as 2.66 gals/bu.

So ethanol yield is 308.7 x 2.66 x 3.785 = 3108 liters/ha.

The net energy value (surplus *useful* energy), as shown in Table 7, bottom line, comprises a co-product credit of 14,372 Btu/gal, to make a total of 21,105 Btu/gal = 5.88 MJ/liter. So net energy-capture (amount of *useful* energy captured per hectare), including co-products, is 3108 x 5.88 x $10^6$ = 18.3 GJ/ha/yr = 18.3 / 31.5 = 0.58 kW/ha.

0.58 kW/ha is an impractically low net energy-capture. This is best shown by the following hypothetical case. Supposing that it were possible to make 50 Mha of cropland (nearly a third of U.S. cropland) available for growing corn for ethanol production, this would produce, 0.58 x 50 x $10^6$ = 29 x $10^6$ kW. For a population of 280 million, this is 29 / 280 = 0.104 kW/cap. As the amount of net power available to the average American is about 9 kW, this is 1.2% of net energy — a tiny reward for the expenditure of 50 million hectares of cropland. That it would be almost impossible to allocate as much as 50 Mha for this purpose is of no concern, since the argument is of the *reductio ad absurdum* type — the premise which is hereby shown to be absurd is this: a *useful* amount of energy can be captured during the process of making ethanol from corn.

## Production of liquid fuel

Although it is clear that it makes no sense to try to capture energy by producing ethanol, there is another possible reason for producing it. Shapouri et al. make the point that it is legitimate to look upon the ethanol program as one which is aimed at producing *liquid* energy, since the energy needed to effect the transformation into ethanol can mainly be derived from "abundant domestic feedstocks such as coal and natural gas." One might query the assertion that domestic supplies of natural gas are abundant,[3] and also question if coal will continue to be abundant in the light of the fact that Gever et al., 1986, reported that the gross output to input energy ratio for U.S. coal fell from 80:1 in the 1940s to 30:1 in the 1970s, but, since we are taking Shapouri et al. at face value, let us start by considering this question: to what extent will U.S. liquid fuel requirements be diminished if 50 Mha of cropland are used for growing corn for ethanol?

On page 11, the report states that "about 83 percent of the total energy requirements come from non-liquid fuels, such as coal, and natural gas. The liquid fuels, which include gasoline, diesel, and fuel oil, account for about 21,700 Btu per bushel."

In conjunction with our previous parameter — an average yield of 308.7 bu/ha — we can see that there is a need for 21,700 x 308.7 = 6.70 x $10^6$ Btu/ha = 7.07 GJ/ha = 7.07 x $10^9$ / 21.3 x $10^6$ = 332 liters of ethanol/ha as input.

So the *net* ethanol yield = 3108 - 332 = 2776 liters/ha.

Thus our 50 million hectares will provide 50 x $10^6$ x 2776 x 21.3 x $10^6$ / 32.5 x $10^6$ = 91 billion liters of *gasoline* equivalent.

U.S. gasoline consumption (March 2000 data) was 480 billion liters per year. 91 billion liters is 19% of that. Gasoline represents about 56% of the oil used in U.S. transport, so the 50 million hectares of cropland would supply about 11% of the liquid fuel used by U.S. transport. To put it another way, it would suffice to meet 10 years of U.S. population growth (at the 1.06% per year rate of the three closing decades of the last century).

It is unlikely that an attempt will be made to find 50 Mha of cropland for producing corn for ethanol when the benefit, *as a gasoline extender*, amounts to satisfying the transport demands of only 10 years of population growth. So let us look at a more realistic figure. Shapouri suggested to me that nobody plans for a future use of even 10 Mha. 10 Mha would provide the transport needs of 2 years of population growth. To put it in yet another light, at least 5 Mha of cropland are needed to satisfy the transport needs of 1 year's growth of U.S. population. It is hard to say *categorically* that it cannot be justified to put 5 Mha of cropland to this use, because that judgement depends on how important it is deemed to be to allow the population to keep expanding, and/or to maintain per capita liquid fuel consumption. Nevertheless, the great majority of people would surely deem it a mistake to use 5 Mha (50,000 $km^2$) in order to provide transport energy for just one year of U.S. population growth; especially because growing corn has many detrimental effects, which we will now consider within the context of 5 million ha being devoted to growing corn — sufficient to provide transport energy for 1 year of U.S. population growth.

Soil erosion is one of the fundamental problems of growing corn. The weight of stover — the residue of harvesting — is about equal to the weight of the crop. With this removed, erosion rates as high as 54 t/ha/yr have been reported, but it is normally left

**Table 1**. Chemicals used for growing U.S. corn, covering both conventional and no-till agriculture

| | Application kg/ha/yr | Used on 5 Mha over 70 years[a] tonnes |
|---|---|---|
| Insecticides | 0.15[b] | 52,000 |
| Herbicides | 2.10[b] | 735,000 |
| Nitrogen | 144.93[c] | 51,000,000 |
| Phosphate | 53.95[c] | 19,000,000 |
| Potash | 66.37[c] | 23,000,000 |
| Total N, P, K | 267.50 | 93,000,000 |

a Useful ethanol production, from 5 Mha, would be 9.1 billion liters a year, 1.9% of U.S. gasoline consumption, or 1.06% of transport consumption — by coincidence, exactly the amount which would be sufficient for providing transport fuel for 1 year of population growth (which was 1.06% per year over the last three decades of the past century). By taking a period of 70 years, the average lifespan, a measure is given of the total impact of one year's increment of people, under this 'ethanol scenario'.

b Average for all U.S. corn, covering both conventional and no-till agriculture (Pimentel, 2002).

c "Nine-State weighted average, 1996." Taken from page 6 of Shapouri et al., 2002.

on the ground, and with conventional agriculture the soil erosion rate associated with growing corn is 15 t/ha/yr (Pimentel et al., 1995). This can be reduced to 5 t/ha/yr by adoption of no-till agriculture (Troeh and Thompson, 1993). The downside of no-till corn production is that it uses more herbicides, insecticides, molluscicides and rodenticides. Leaving this stover on the ground has the effect of keeping the soil moist, and suitable for slugs, providing an excellent habitat for mice, and results in more insect pests and plant pathogens attacking the corn. Despite these problems, Pimentel (2002) favors no-till agriculture for corn because it reduces soil erosion by over 50%. Since about 50% of US corn production is no-till, the average rate of soil erosion when growing corn is 10 t/ha/yr, or 50 mm in 70 years. 5 cm in a lifetime may not seem much, but 5 cm may be critical for substantial areas which already have thin soils. The other fundamental problem is that pesticides have an unquantifiable penalty in terms of damage done to insect life, and hence to the animals that feed on them and to biodiversity. And nitrogen pollution is already a serious problem, which causes both air pollution and contaminates water supplies.[4] The cost of dealing with excess nitrates in water is another hidden cost of ethanol production.

Based on average U.S. corn production, the 5 million hectares under consideration, sufficient for the transport needs of 1 year's population growth, would require, over a lifespan of 70 years, 52,000 tonnes of insecticide, 735,000 tonnes of herbicide, 51 million tonnes of nitrogen, 19 millon tonnes of phosphate and 23 million tonnes of potash (Table 1). Also 5 cm of soil would be lost.

**The implications of USDA Report Number 814**

Shapouri et al.'s comprehensive, and brilliantly presented study of the entire range of earlier work done on the energetics of ethanol production leads to unequivocal conclusions:

1. Overall, ethanol increases atmospheric pollution. But when ethanol is being produced as a gasoline *enhancer*, to reduce *tail pipe* emissions, no clear boundary can be set at which the energy efficiency of ethanol production becomes unacceptable.

2. The amount of energy produced — as *useful* energy in liquid form — is so small in relation to the area of land needed to produce it, that the production of ethanol as a gasoline *extender* cannot be justified, especially in view of the associated environmental damage.

**Acknowledgment**

My thanks are due to David Pimentel, of Cornell University, not only for having brought the Report to my attention, but also for giving a great deal of help in developing the paper, by researching the relevant data on the detrimental ecological effects of growing corn under current U.S. agricultural practices, and much other valuable advice.

## Endnotes

1. United States Department of Agriculture (USDA), Agricultural Economic Report Number 813, by Hosein Shapouri, James A. Duffield, and Michael Wang, dated July 2002.

2. Probably the most authoritative survey of the use of ethanol in cars is that of Cal Hodge in the *Oil & Gas Journal*, Sept. 9, 2002, pp. 20-28. Hodge raises serious concerns about emissions at production plants. Omitting that aspect, I will quote him, compressing his conclusions concerning tailpipe emissions (mainly about the number of occasions on which legal limits on air pollution were exceeded) into the smallest possible compass:

   > Using ozone is more likely to increased ozone exceedances and cancer risk. . . . Its use in reformulated gasoline [between the two periods 1993-94 and 1995-96] caused ozone exceedances to double.
   >
   > America should wait to see if California's switch to ethanol confirms or denies that ethanol increases ozone . . . If we do not want to wait for the outcome of the California experiment, the use of ethanol in motor gasoline should be banned, not expanded.

   Turning now to 'off-scene' pollution, in addition to ethanol plant emissions, since coal and gas are used for 83% of the input (page 11 of the report), the situation seems to be this. The coal and gas combustion will amount to 0.83 x 77,228 = 64,099 Btu/gallon, or 64,099 / 83,960 = 76% of the high heating value of the ethanol; thus the total release of fossil carbon may not be reduced at all (coal has a high carbon content), moreover carbon dioxide is far from being the only pollutant from burning coal. For the remaining 17% of inputs, liquid fuels are required. These would amount to 0.17 x 77,228 = 13,129 Btu/gallon, or 13,129 / 83,960 = 16% of the HHV of ethanol. Thus 100 units of ethanol energy emerging from the tail pipe will be associated with 76 + 16 = another 92 units burnt 'off-scene'. In the main text, I gave a figure of 75 instead of 92. This is because Shapouri et al. increase the energy ratio to 1.34 by allocating some inputs to co-products.

But even an *additional* emission of 75% still suggests fairly strongly that overall atmospheric pollution is increased by ethanol combustion.

3. U.S. natural gas *production* has roughly flat-lined for the last twenty years, at around 19 trillion cubic feet a year (tcf/yr). In the year 2000, US natural gas *consumption* was about 22 tcf. Between 1985 and 2000, imports from Canada increased by about 2.5 tcf/yr, to make up the difference. The increasing imports from Canada *might* just be because Canadian gas was cheaper, so U.S. gas producers consequently saw little profit in making substantial investment to expand production. However, that does not appear to be the explanation; rather it is increased difficulty in obtaining the gas: Texas, which produces one-third of US gas, in 1999 had to drill 6,400 wells to keep up its production, whereas 4,000 were sufficient in 1998. Neither are Canadian resources unlimited: Canadians are having to drill nearly 7,500 wells a year to keep up Alberta's production.

   Other reasons for doubting that U.S. natural gas supplies can be regarded as "abundant" are, first, that the Energy Information Administration have suggested that by 2015 the US may need 50% more natural gas than today, i.e. another 11 tcf/yr. The Energy Administration did not say where this was to come from. Secondly, during 2001 natural gas prices in the U.S. increased by an amount ranging from 33% to 50%, depending on location (Pimentel, 2002).

4. Problems of the nitrogen cycle were summarised by Danielle Nierenberg, in the March/April, 2001 issue of *World Watch*, in an article titled *Toxic Fertility*. It had the caption, "Over the past half century, the amount of biologically active nitrogen circulating through the world's living things has probably doubled. In unnatural excess, an essential nutrient is becoming a kind of ecological poison."

   Extracts relevant to corn-based ethanol production, and the associated problems, are: "Fertilizer is often very inefficiently applied; much of it never reaches the crop. It leaches out of the fields and into the streams, or it's converted into a nitrogenous gas like nitrous oxide and escapes into the atmophere. . . . Three basic reforms appear to be necessary if we are to achieve major reductions of our fixed nitrogen emissions. We will need to convert the dominant mode of agricultural production from its current, 'high input' paradigm to one that emphasizes organic production. . . . "

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## A PLAIN MAN'S QUESTIONS CONCERNING LIQUID SUNSHINE

Asked by Edmund Davey; answers provided by Andrew Ferguson

*Edmund* I know that nearly all experienced petroleum geologist are predicting that the world will be short of petroleum before long; indeed they generally indicate that it will be soon after the middle of this century that oil supplies will be half what they are today, and natural gas does not have a much longer life than oil. So what are we going to do? How are we going to convert current sunshine into 'liquid sunshine' once easily available fossil energy runs out?

*Andrew* You are quite right Edmund, producing 'liquid sunshine' from renewable resources is the most intractable problem facing the human race. But what precisely is troubling you?

*Edmund* What troubles me is that nothing you have looked at so far seems to hold out any promise. You showed that the only place which is likely to have enough renewable energy to make liquid hydrogen is Iceland, with its huge endowment of hydro and geothermal power. Another possibility was methanol, but we learnt, on page 16 of the October 2002 *OPT Journal*, that net energy-capture would be in the range of 0.4 to 1.3 kW/ha, and the upper figure was somewhat speculative. So I have been looking for some way out. I took a careful look at your study of the United States Department of Agriculture (USDA) ethanol report, and came to the conclusion that you have been painting a blacker picture than necessary.

*Andrew* I'll admit there is some truth in that, but explain what you found.

*Edmund* It occurred to me that when you asserted that the net energy capture was only 0.6 kW/ha, you arrived at that result by merely subtracting the inputs from the calorific value of the ethanol output, and adding the value of the by-products. As I see it that implicitly assumes that all the inputs need to be in the form of ethanol.

*Andrew* You are a brilliant fellow Edmund! What you say is true. It was misleading to an extent, but I didn't do it to mislead, but merely because people seem to find difficulty with the whole concept of net energy, that is the amount of *useful* energy which is captured, so I wanted to keep the analysis as simple as possible, even though I know it is a simplification. Tell me more about what you found.

*Edmund* It seems to me one must separate out the non-liquid inputs. According to Shapouri et al., the non-liquid inputs amount to 83% of the ethanol output, which we could satisfy with another 1.7 kW for each ha of cropland.[1] Now it seems to me that the best way to satisfy that input is to use biomass. I know that you usually say that a sustainable yield of biomass is 3 tonnes per hectare per year, but if we put on rose-tinted spectacles, couldn't we push that up to say 8.5 t/ha, at least in certain places?

*Andrew* That is not implausible. Giampietro et al., in their paper, *Feasibility of Large-Scale Biofuel Production* (1997), considered a yield of short-rotation woody biomass of about 10 t/ha/yr, 85% dry, which indicates 8.5 dry t/ha.

*Edmund* O.K. then, that means we would only need 0.32 ha to supply the non-liquid input energy, which works out at an overall net energy-capture, in liquid form, of 1.42 kW/ha.[2] According to Shapouri et al., the co-product credit would amount to 0.4 kW/ha.[3] So that is a total of 1.8 kW/ha. Isn't that three times the 0.6 kW/ha that you gave?

*Andrew* You have done a good job there Edmund! It is indeed three times as much, but it does not change the essence of the conclusion about net energy-capture. You will recall that I calculated that the huge area of 50 Mha would only produce about 1.2% of the net energy used in the USA. Your three-fold improvement raises that to 3.6%, but that is still trifling compared to the use of 50 Mha. The really vital point is that the 1.42 kW/ha that you calculated, in terms of useful *liquid* fuel, is a very inadequate rate of energy-capture to sustain anything but a small population.

*Edmund* I think I see your point, but can you make it absolutely clear to me why the amount of liquid fuel per hectare has actually dropped.

*Andrew* Yes indeed. By dropping Shapouri et al.'s assumption that either gas or coal would be available to supply the non-liquid inputs, you are dealing another blow to optimists! Thus while I was able to say that the useful yield of ethanol would be 2776 liters per hectare, you are now suggesting that another 0.32 ha is needed to provide the non-liquid inputs. That reduces the yield to 2776 / 1.32 = 2103 liters per ha, which gives the 1.42 kW/ha that you calculated earlier. To put it another way, the useful yield per hectare is now 2103 / 2776 = 76% of what I calculated on page 12. There I showed that even 2776 liters/ha was hopeless, because 5 Mha of cropland would be needed to satisfy the transport needs of 1 year of U.S. population growth. What you are essentially saying is that in addition to that 5 Mha of cropland, another 0.32 x 5 = 1.6 Mha of short-rotation woody crops would be needed.

*Edmund* O.K. I get the picture now: with a more sophisticated analysis, it is possible to bump up the overall energy-capture figure well above the 0.6 kW/ha you indicated, but the amount of useful liquid energy we are going to get puts the whole idea right out of court anyhow, especially taking into account the damage done by the immense amount of chemicals needed. So I fully appreciate the difficult of reaching that mean figure of 3 kW/ha that we proposed for eco-footprinting. Probably the currently used 2.5 kW/ha is closer to reality.

And perhaps an even more important thing about eco-footprinting, is that the usually quoted 20 to 30% overshoot of biocapacity is a vast underestimate, because no account is taken of unsustainable agricultural practices, or the fact that half the present population is suffering from malnutrition. So I conclude that we must aim to make a substantial reduction of population before fossil fuels become scarce.

*Andrew* By Jove Edmund, you sometimes take my breath away with your facility to see reality with sparkling clarity.

## Reference

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## Endnotes

1. Total output of ethanol is 3108 litres/ha/yr (p. 11), so at 83%, non-liquid input = 0.83 x 3108 x 21.3 x $10^6$ = 54.95 GJ/ha/yr = 54.95 / 31.54 = 1.74 kW/ha.
2. 8.5 t/ha at 20 GJ/t = 170 GJ/ha/yr = 170 / 31.54 = 5.39 kW/ha.
   The required input of 1.74 kW, at 5.39 kW/ha needs 1.74 / 5.39 = 0.32 ha.
   Ethanol available after subtracting liquid inputs is 2776 liters/ha (p. 12), = 2776 x 21.3 x $10^6$ = 59.13 GJ/ha/yr = 59.13 / 31.54 = 1.87 kW/ha. So energy-capture in liquid form = 1.87 / (1 + 0.32) = 1.42 kW/ha.
3. Co-product credit = 14,372 Btu/gal = 14,372 x 1055 / 3.785 = 4.006 MJ/litre.
   Ethanol yield is 3108 litres/ha. So energy-capture from co-product alone = 3108 x 4.006 x $10^6$ = 12.45 GJ/ha/yr = 12.45 / 31.54 = 0.395 kW/ha.

Regular *OPT Journal* readers will recall that the April 2002 issue (pp. 27-30) carried a piece on *The Population Implications of Houghton's "Global Warming: the Complete Briefing*." OPT member, Jo Hanson, kindly sent me the Summer 2002 issue, No. 49, of *Green Christians,* the Journal of Christian Ecology Link. It contained a couple of pages recording Mike Monaghan interviewing Sir John Houghton. Here is a brief extract:

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## GLOBAL WARMING: EXTRACT TAKEN FROM AN INTERVIEW WITH SIR JOHN HOUGHTON

**Sir John, could you explain how the IPCC works and how authoritative are its findings?**

The IPCC was formed in 1988. It has two parents, the World Meteorological Organisation and the United Nations Environment Programme. It gains its authority from the attendance at its plenary meetings of representatives from all governments around the world — typically 120.

I became chairman of the scientific assessment group in 1988. From the outset we involved hundreds of leading scientists from as many countries as possible in writing and reviewing our reports. These reports are, we believe, extremely authoritative and there are now very few scientists who disagree with the findings (and most of those have a vested interest to protect and none of them are leading climate scientists). These reports have been accepted by all governments from a wide range of political opinion including the USA and importantly Saudi Arabia. . . .

**By how much do we need to reduce the emission of greenhouse gases if we are to stabilise the temperature at an acceptable level?**

The Royal Commission on Environmental Pollution came up with a figure for the UK of a 60 per cent reduction compared with 1990 by 2050. I would still accept this as a sensible and eminently achievable target. We may have to make deeper cuts subsequently. [Sir John's "still" may refer to the fact that, in 1992, the IPCC stated that a 60 to 80 per cent cut in world emissions was necessary in order to stabilize the concentrations of atmospheric carbon at 1990 levels]. . . .

**What is your view of the position taken by the USA on these matters?**

I think it is very sad that the biggest generator of greenhouse gases in the world is taking such a negative and arrogant attitude and that they are taking this position as a result of the pressure from vested interests such as big coal and some oil companies. It should not be forgotten, however, that a leading contribution to the work of the IPCC in quantity and quality has come from US scientists and that there are now signs that US public opinion is not happy with the stance of the US government.

I hope that there will be a change in position in the US which may well be led by industry, as it begins to realise that this presents opportunities if tackled in a positive way.

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Professor Virginia Deane Abernethy, in a conference on *Poverty: Its Causes and Cures*, at Claremont California, October 2001, gave several reasons why rapid population growth in the United States is an important factor in the growing chasm between rich and poor. Rosamund McDougall kindly sent me a cutting, from the *New Statesman*, 4th November 2002, which contained an article by Anthony Browne, environment editor of *The Times*. He shows the obverse side, namely the benefits of a declining population:

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**DECLINING POPULATIONS: FROM AN ARTICLE BY ANTHONY BROWNE**

A declining population — and this is why businesses fear it — will involve a gradual but significant redistribution of power from the owners of capital to the owners of labour. A declining workforce puts those who work in a far stronger position — and for those marginalised in the workforce, it can have a very dramatic effect. Companies will be forced to train the unskilled, provide family-friendly policies to retain women and to entice the elderly to stay on rather than forcing them out. People who own properties will have to rent them out at lower rates, while those who rent can choose bigger places to live.

The dramatic and beneficial effects of this transfer of power from the owners of productive assets to the owners of labour — from the employers to the employed — were seen after the Black Death, which cut the population by a third, led to the collapse of feudalism and heralded the "golden age of peasants." Landowners could no longer force the landless to work for them for free under the bonds of feudalism — the shortage of labour was such that the peasants could go elsewhere to get paid real wages. The deaths from the disease may have been devastating, but the lives of those left behind improved dramatically.

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**WAS JOHANNESBURG A WSII?** by Andrew Ferguson

Philip Stott, Professor Emeritus of Biogeography at the University of London, contributing a "Comment" piece to *The Daily Telegraph*, 27th August 2002, put forward a simple proposition. It was that poor people need more energy, and renewable sources are not going to supply it, so they need to use more hydrocarbons. While there is a grain of truth in that, the associated problems become apparent only when one does the arithmetic.

Let us suppose that the four-fifths of the world which is energy-poor increases the use of hydrocarbons slightly. We won't choose the USA as an example, because everyone knows that Americans are using energy in a profligate manner. Neither will we choose Europeans, who use only half as much per capita as the Americans. Instead, let us assume that the poor four-fifths of the world increases its energy use until it is just a *quarter* of the US rate.

On these assumptions, world emissions from burning fossil fuels would be 10 billion tonnes of carbon a year. That is *four* times the limit calculated by the IPCC as what is needed in order to stabilize the concentration of carbon dioxide in the atmosphere. Moreover, it is generally agreed that it is the poor who would be the first to suffer under the likely result: runaway global warming.

The conclusion is this: in order for the world to 'develop', population needs to be about 2 billion rather than the 6 billion it is at present. Of course Stott is far from the only person to wish to gloss over that uncomfortable fact. If understanding of that reality had been more widespread, then perhaps the Johnnesburg conference would have assumed a more candid title, such as *World Summit on an Impossible Idea* (WSII).

## YES, JOHANNESBURG WAS A WSII

by Andrew Ferguson

Since it became apparent in the previous piece, *Was Johannesburg a WSII?*, that even moderate development of the undeveloped world would result in exceeding, *by a factor of four*, the capacity of the world to absorb emissions from burning fossil fuels, an unbiased judge* would surely be left in no doubt about the answer to the question that was posed by the title; and would conclude that Johannesburg was indeed a World Summit on an *Impossible Idea*.

However, there are many *biased* judges around (of whom Bjorn Lomborg, Professor of Statistics is the incumbent archetype, having assumed the mantle from the late Julian Simon, Professor of Marketing). Such people prefer to believe that their own judgement about the effects of climate change is better than that of the Intergovernmental Panel on Climate Change, the Royal Society, and several national academies of science. As a riposte to those who espouse hope rather than reason when it comes to climate change, it may be helpful to pursue another path, using data published in the September/October 2002 issue of *World Watch*.

It was stated in that issue, page 2, that: “Almost four-fifths of the world’s commercial timber harvest is consumed by the one-fifth of the world’s people living in North America, Europe, and Japan.” Furthermore, it was recorded, on page 38, that while 14.6 million hectares (Mha) of forest are cleared each year, only 5.2 million ha of afforestation takes place. In other words, forest is being lost at the rate of 9.4 Mha per year (over the period 1990-2000, equal to the combined sizes of Spain, Portugal and Italy), so it would seem that even present levels of demand for timber are unsustainable.

Let us now consider what would happen if each undeveloped fifth — of the four-fifths of the world’s people who are currently consuming only 20% / 4 = 5% of the world’s timber — were to take a moderate step towards the aforementioned developed fifth of the world, by increasing their consumption to just *half* its level. That would make total world consumption of commercial timber 80% + (4 x 40%) = 240% of its present rate. Since, as we noted, the world is already exceeding the Earth’s forest capacity, we can conclude that, for the world to take even this modest step towards the currently impossible idea of ‘sustainable development’, population would need to be reduced to about 1 / 2.4 = 40% of its present level; that is to about 2.6 billion people.

We might pause to note that other impossible ideas were being batted around at Johannesburg. For instance, that of providing basic sanitation facilities for everyone lacking such facilities (the agreed first step was halving, by 2015, the current number, 2.4 billion, of those who lack such facilities). While it is difficult to apply precise arithmetic to that aspiration, its viability seems dubious when: “On current trends, by 2025 half the world’s population will live in countries facing water scarcity.” (*New Scientist*, 7 September 2002, page 10). The important point, though, is that for present purposes — a world overview — we do not need to analyse other constraints, or use the more complex considerations of eco-footprinting, because excessive demands on the world’s carbon sinks and forests suffice to show that ‘sustainable development’ only becomes a ‘*Possible Idea*’ after getting the human population down to a sustainable 2 billion.

* A completely ‘unbiased judge’ is probably a chimera, but the reference here is intended to be to someone who makes an earnest attempt to avoid the temptations of unreason, and thus avoids, in particular, that hoary old favourite: “selection of the evidence.”

## CHINA'S SUCCESS CANCELLED OUT BY THE USA

by Andrew Ferguson

Our founder and late chairman, David Willey, used to suggest that China should be awarded the Nobel peace prize for tackling their population problem. A report by Damien McElroy, writing from Beijing, which appeared in *The Daily Telegraph* 30th July 2002, suggests that he was right.

One of the richest Chinese provinces, Guangdong, has raised fines for a second child, to eight times the couple's annual income. A measure of the success of Chinese policies is contained in their claim that since the early 1980s, 330 million births have been prevented. Moreover, the Chinese Family Planning Agency is continuing with its "uncompromising drive to limit the population to 1.6 billion by 2050."

What China is doing, the USA is undoing. As measured by their respective Ecological Footprints (*Living Planet Report 2002*), a U.S. citizen has 6.3 times the impact of a Chinese citizen.[1] Thus during the last twenty years, while the Chinese have prevented 330 million births, the Americans have, by the impact of their population growth, added the equivalent of 340 million Chinese.[2]

The prospects for 2050 are worse. While China's "uncompromising drive" should manage to limit China's population growth to about 330 million, during the same time the U.S. will, at the rate of U.S. population growth of the three closing decades of the last century, add the equivalent of another 1190 million Chinese.[3]

This impact is an underestimate, because whereas the impact ratio as measured by the Footprint is the aforesaid 6.3 to 1, when assessed by fossil fuel emissions alone, the ratio is 8.4 to 1.[4]

The *Living Planet Report 2002* also shows why there is a *national* imperative for China to take action. By the time it has a population of 1.6 billion, China will have only 0.5 global hectares of ecologically productive land per person. That compares to Afghanistan's current 0.7 global hectares per person, and Rwanda's 0.8 global hectares per person. (Those figures give a cue to remind readers that our website <www.optimumpopulation.org> contains not only the vitally important Table 2 spreadsheet, of the *Living Planet Report 2002*, but also an extension to it, showing its implications for national carrying capacities).[5] The pressure on the United States is of a different kind. By 2050, it will still have an estimated 2.75 global hectares per person.[6] But at the current rate of per capita emissions, the United States *alone* would by then be emitting 6% more carbon dioxide than the limit calculated by the Intergovernmental Panel on Climate Change as being applicable to *the whole world*, in order to achieve stabilization of carbon dioxide concentration.[7]

### Endnotes

1. USA/China impact ratio, based on total ecological footprints (WWF, 2002), = 9.70 / 1.54 = 6.3.
2. US growth rate 1970-2000 = 1.06% pa.

   U.S. population as of June 1, 2002 = $287.2 \times 10^6$ (www.census.gov).

   Therefore U.S. growth over past 20 years = $287.2 \times (1 - (1 / 1.0106)^{20}) = 54.6$ million.

So additional impact = $54.6 \times 10^6 \times 6.3$ = 344 million Chinese.

3. Chinese growth to 2050 = 1600 - 1270 = 330 million.

   US growth to 2050 = $(1.0106^{48} - 1) \times 287.2 = 189.2 \times 10^6$.

   So additional impact = $189.2 \times 10^6 \times 6.3$ = 1192 million Chinese.

4. Fossil fuel ratio as assessed by WWF 2002 = 5.38 / 0.64 = 8.4.

5. As is explained in an extensive commentary on the Living Planet Report 2002 (from WWF), now on our website <www.optimumpopulation.org>, there is a substantial error in Table 2 of that report in the assessment of China's grazing land biocapacity. It is shown as 0.44 gha/cap, whereas it should be 0.13 gha/cap, thus a reduction of 0.44 - 0.13 = 0.31 gha/cap is required on that count.

   Thus China's ecologically productive land, using corrected LPR 2002 figures, is 1.04 - 0.31 - 0.09 [built-up] = 0.64 gha/cap. By 2050 it is likely to have doubled its use of built-up land (as per Smil, 1993). Combining this with the increase in population from 1.272 billion to 1.6 billion leaves it with (0.64 - 0.09) x 1.272 / 1.6 = = 0.44 gha/cap. This is rounded up to 0.5 gha/cap in the main text.

   Afghanistan's ecologically productive land in 1999, as per LPR 2002, is 0.78 - 0.06 [built-up] = 0.72 gha/cap.

   Rwanda's ecologically productive land in 1999, as per LPR 2002, is 0.92 - 0.12 [built-up] = 0.80 gha/cap.

6. By 2050, the US 1999 population of 280.4 million would become, at the rate of growth of the three closing decades of the last century, $280.4 \times 1.0106^{51}$ = 480 million.

   America's ecologically productive land in 1999, as per LPR 2002, is 5.27 - 0.37 [built-up] = 4.90 gha/cap. Loss of ecologically productive land would be less severe than China, as the infrastructure is more developed, but a 50% increase is in the ball park. Adjusting for this, and the population change, leaves the US in 2050 with (4.90 - (0.37 / 2)) x 280.4 / 480 = 2.75 gha/cap.

7. U.S. per capita emissions in 1996 were 5.37 x 3.664 = 19.7 t $CO_2$/cap (Engelman et al., 2000). At this emission rate, with a population of 480 million, the US would be emitting 19.7 x 480 = 9456 t $CO_2$/yr. The limit for the whole world, if the atmospheric concentration is to stabilize is, as calculated by the IPCC, 8900 t $CO_2$/yr (Engelman, 1994, page 27). Thus the U.S. overshoot of the global limit is 9456 / 8900 - 1 = 6%

## References for endnotes

Engelman, R. 1994. *Stabilizing the Atmosphere: Population, Consumption and Greenhouse Gases*. Population Action International, 1300 19th Street, NW Second Floor, Washington, DC 20036, USA. Tel: 202-557-3400. 48 pp.

Engelman, R., Cincotta, R.P., Dye, B., Gardner-Outlaw, T., Wisnewski, J. 2000. *People in the Balance.* Population Action International, 1300 19th Street, NW Second Floor, Washington, DC 20036, USA. Tel: 202-557-3400. 32 pp.

Smil, V. 1993. *China's Environmental Crisis: An Inquiry into the Limits of National Development*. U.S.: M. E. Sharpe. pbk 1 56 324 041 6 (£18.95).

WWF, 2002; World-Wide Fund for Nature International, UNEP World Conservation Monitoring Centre, Redefining Progress, Center for Sustainability Studies. *Living Planet Report 2000*. Ed. J. Loh. Ecological Footprints led by M. Wackernagel. WWF, Gland, Switzerland. (36 pp.).

Edward Goldsmith's words, reproduced on the front page of this issue of the *OPT Journal*, provide a sample of the arguments which are marshalled against a global economy by the twenty-four contributors to, *The Case Against the Global Economy & for a Turn Towards Localization*, edited by Edward Goldsmith and Jerry Mander (*Earthscan*, 2001).

A catalogue of books, to be published by Zed during March - September 2003, contains fifteen titles in which the main aim appears to be to show up the damage being wrought by globalization. For instance, the catalogue describes *Juggernaut Politics*, by Jacques B. Gelinas, in these words:

> Globalisation is not a vehicle without a driver, or an irresistible and inevitable force of nature, as political leaders and pundits would have us believe. *Juggernaut Politics* identifies the actual institutions and people controlling the system, and explains:
>
> How the globalisation machine really works:
>
> - The hidden face of the unregulated global market - its unequal trade treaties and domination by big money.
> - The masters - the transnational corporations and speculators.
> - The overseers - the supermanagers and subservient politicians.
> - The ideologists who justify and defend the system - the free market economists and media pundits propagating the Globalisation Creed.

Thus there is a wealth of material to turn to. The excuse for reprinting what follows is that perhaps it provides as brief a summary of the main points as can be easily achieved.

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## THE SOCIAL AND ECOLOGICAL CONSEQUENCES OF GLOBALIZATION

by Andrew Ferguson

The Optimum Population Trust has long realized the importance of focusing on our one main objective, namely to get agreement about national carrying capacities. However globalization — making the world into a free market for capital and goods — does have implications for carrying capacity, as well as many dire effects, so we think it is now time to produce a final version of this paper, which was first circulated as a "discussion paper" in April 1999. The comments we received supported our views, so only minor revisions have been made. We believe that globalization is the cause of, or is at least deeply implicated in, the following woes of mankind:

1. Globalization diminishes people's awareness of any need for *each nation* to keep within its own ecological capacity. For example, The Netherlands and Egypt both live wildly beyond their ecological capacity, but many people imagine this does not matter because globalization makes the ecological resources of the world available to anyone with money to purchase them. Money does indeed have that effect, but, in a full world, only at the expense of others.

2. Globalization diminishes the power of "labour," transferring the power to "capital," and thus increases the gulf between rich and poor. This has been set out with great clarity by James Goldsmith in *The Response* (1995), particularly in chapter 3: "Global free trade and its effects on jobs and wages in developed economies." James Goldsmith was

an outstandingly successful businessman (at his death worth about US$ 1.5 billion), with a good grasp of classical economics, so it is reasonable to suppose that he knows what he is talking about. The extent of the great and growing division between rich and poor, and the consequences for carrying capacity, are well covered in Ehrlich, Ehrlich and Daily's, *The Stork and the Plow: The Equity Answer to the Human Dilemma* (1998).

3. There is another process by which globalization serves to make the powerful rich, and the weak poor, as explained in Clive Ponting's *A Green History of the World* (1992): The élites who inherited colonial power want the goods which the developed world produces, such as arms, aeroplanes, and Mercedes, so many national leaders favour the production of cash crops, although it would benefit the poor to use the land to produce food for their own consumption. Yet another way in which globalization causes the powerful to grow rich at the expense of the poor is the confiscation, from the indigenous population, of forests, or land containing mineral wealth, so that the 'rights' can be sold to the highest international bidder. Ted Trainer (1996) covers similar ground in detail.

4. Globalization involves moving products around the world, which of course requires energy. This is one significant reason why the world as a whole is burning fossil fuels at a rate which is at least two and a half times greater than that which the Earth's carbon sinks can accept. The estimate is based on a recommendation by the Intergovernmental Panel on Climate Change that, to stabilize the concentration of carbon dioxide in the atmosphere, emissions need to be reduced to 20-40% of 1990 levels. Robert Engelman's pamphlet, *Stabilizing the Atmosphere: Population, Consumption and Greenhouse Gases* (1994), is an admirably simple introduction to the carbon dioxide emission problem. Also excellent is Sir John Houghton's *Global Warming: The Complete Briefing* (1997). Of particular interest, in Stephen Schneider's *Laboratory Earth: The Planetary Gamble We Can't Afford to Lose*, (1996:153), is his report that 15 out of 16 scientists concluded that without a change in policy there was a non-trivial possibility of a catastrophic runaway greenhouse effect.

5. Globalization introduces much insecurity into the lives of most people. For instance *without* globalization, a small well-run business — satisfying the local community and bringing local employment both directly and indirectly — could contemplate a secure future. However *with* globalization, a multinational can choose at any time to swamp a local market with goods produced where labour costs are lower and environmental restrictions weaker. The full effects of this unfortunate situation have been admirably described by Ted Trainer in a series of books, culminating in his latest book *Towards a Sustainable Economy* (1996).

6. Globalization facilitates organised crime. This is well covered in Richard Buckley's pamphlet *Organised Crime: a Growing Threat to Democracy?* (1999). He says, "Organised crime could not prosper without the help, direct or indirect, of the global financial system, which allows for the rapid transfer of 'dirty' money through a maze of anonymous companies and offshore banks until it emerges 'clean' - and ready for investment in legitimate businesses, thus corroding the fabric of civilized democratic society." The International Monetary Fund substantiate the truth of this assertion with their estimate that $500,000 *million* is the *net gain* accruing annually from organized crime. Equally striking is the estimate that $300,000 *million* has been exported from Russia over the last decade by the communist élite.

From the above, it will be clear that while economists, the media and politicians (the chief purveyors of popular delusions) remain in bond to the idea of globalization, there can be little hope of reducing human impact on the environment, or improving the quality of life for most of its inhabitants. It is hard to grasp the fact that so many august bodies are prey to a delusion, but that difficulty can be overcome by reading Mackay's *Extraordinary Popular Delusions and the Madness of Crowds*. Many *ecological* economists have made withering attacks on conventional economics, but perhaps none more lucidly than Ted Trainer in his recent book, *Towards a Sustainable Economy*, particularly Chapter 11, *The basic mistakes in conventional economic theory*. As well as showing that conventional economics is the source of our current ills rather than their cure, he also satisfactorily explains why a discipline which is so hopelessly flawed nevertheless perpetuates itself.

Since this paper was first circulated, many books have been published on the subject of globalization, and there are many internet sites and papers too. We would like to pick out two papers as being superb: (1) *Small is Beautiful, Big is Subsidised: How our taxes contribute to social and environmental breakdown*, principal author Steven Gorelick; (2) *Globalising Poverty*, a sixty page section bound into the September 2000 edition of *The Ecologist*.

## References

Buckley, R. 1999. Organized Crime: a Growing Threat to Democracy? *Understanding Global Issues*, 99/1.

Ehrlich, P.R., A.H. Ehrlich, and G.C. Daily. 1998. *The Stork and the Plow: The Equity Answer to the Human Dilemma*. New York: G.P. Putnam's Sons. ISBN 0-399-14074-3

Engelman, R. 1994. *Stabilizing the Atmosphere: Population, Consumption and Greenhouse Gases*. Population Action International, 1300 19th Street, NW - Second Floor, Washington, DC 20036, USA

Goldsmith, J. 1995. *The Response*. London: Macmillan.

"Globalising Poverty". A sixty page report bound into *The Ecologist*, September 2000, Volume 30 No. 6. The whole *Ecologist* Volume costs £3.50.

Steven Gorelick (principal author), with an introduction by Helena Norberg-Hodge. October 1998. *Small is Beautiful, Big is Subsidised: How our taxes contribute to social and environmental breakdown*. International Society for Ecology and Culture (ISEC). In the UK: Apple Barn, Week, Dartington, Devon, TQ9 6JP. £5 will cover the cost. In the US: P.O. Box 9475, Berkeley, CA 944709. email: isecca@igc.apc.org.

Houghton, J. 1997. *Global Warming: The Complete Briefing*. Revised edition. U.K. Cambridge: Cambridge University Press.

Ponting, C. *A Green History of the World*. 1992. Penguin.

Mackay, C. 1841. *Extraordinary Popular Delusions and the Madness of Crowds*. Reprinted in 1995 by Wordsworth Editions Ltd. ISBN 1-85326-349-4 (pbk). £3.

Schneider, S.H. 1996. *Laboratory Earth: The Planetary Gamble We Can't Afford to Lose*. London: Weidenfeld & Nicolson.

Trainer, F.E. (Ted) 1996. *Towards a Sustainable Economy*. England: Jon Carpenter Publishing; Australia: Envirobook.

In the ensuing dialogue, Secretary of the Optimum Population Trust (UK), Edmund Davey, takes the role of the 'Plain Man', asking questions of interest to himself and other members of OPT.

## A PLAIN MAN'S QUESTIONS CONCERNING ECO-FOOTPRINTING

Asked by Edmund Davey; answers provided by Andrew Ferguson

*Edmund* *Part I* of the *2nd Footprint forum* seemed to sort out the point at issue pretty well, but I could not help wondering whether the short quotations that you gave from Rees and Wackernagel covered everything that they managed to conjure up in defence of the carbon absorption paradigm.

*Andrew* I don't think I left out anything, within the narrow limitations of what I intended *Part I* of the forum to be discussing. Their original responses were fairly lengthy, but that was mainly because they were exploiting the loophole that I had left by not defining the intended audience as being those who had already grasped the concepts of eco-footprinting. This left scope to expatiate on the whole philosophy of eco-footprinting, with only cursory attention to the point at issue.

*Edmund* I thought that would probably be the explanation. As a result of the *2nd Footprint forum, Part I,* it now seems obvious that the carbon absorption paradigm was flawed because of the temporary nature of the proposed carbon sink. What slightly puzzles me is why this did not become apparent long ago.

*Andrew* I think it is fair to say that in the Forum in *Ecological Economics*, in March 2000, several of the contributors, in addition to Herendeen whom I have already mentioned in this context, noted the problem of the temporary nature of carbon absorption. However they did not focus all their guns on that one aspect. For instance, Robert Ayres, in his contribution to the Forum, said, "There are other ways to generate useful energy without producing carbon dioxide, ranging from nuclear electricity to windmills, tides, water power and photovoltaic (PV) electricity."

Thus although several people have recognized the problem in general terms, they did not find a way of putting the argument strongly enough to make it clear that the carbon absorption paradigm had to be abandoned. Those defending the paradigm, particularly Wackernagel, would tend to argue that although the paradigm might not be 'fireproof', that really did not matter, because the energy/land ratio was approximately correct according to several other measures. It was a somewhat plausible defence, and I must say it took me some time to realize that the weakness in it was that there were problems in running two paradigms in tandem, one determining the *starting* value of an escalating overshoot, and the other being a measure of a basically stable overshoot figure.

*Edmund* Do you think that anyone will still cling on to the carbon absorption paradigm?

*Andrew* I would not like to predict that, but if anyone does, I have a reasonable request that I would like to put to him or her. I would say, "You will know, or course, that if the U.S. population continues to expand at its present rate, while maintaining its *per capita* emissions, then by about 2050 the US will, by itself, be emitting the amount of carbon dioxide which is allowed for the whole world in order to achieve stabilization of carbon dioxide in the atmosphere. Since eco-footprinting, *under the carbon absorption paradigm,* takes account of emissions, could you explain how to make use of eco-footprinting to demonstrate that alarming fact." You will recall I did the arithmetic pertaining to US emissions in *China's success cancelled out by the USA* (page 22, endnote 7).

*Edmund* I can see that a lot of dodging and weaving would be needed to answer that question! Turning now to another paradigm that was mentioned, namely that of replacing energy with wood, it seems to me a bit odd that anyone should contemplate having such an unrealistic paradigm. Perhaps it would help me to understand, if I knew how thinking on the energy footprint has developed.

*Andrew* Perhaps. Anyhow the matter is of general interest. On page 72 of *Our Ecological Footprint*, Wackernagel and Rees considered three paradigms. The first was substituting ethanol and methanol for the energy we use. That of course would have produced a very low energy/land ratio — something below 1 kW/ha. The second was the notorious carbon absorption paradigm, which was at that time associated with 3.2 kW/ha. The third method was the 'energy replacement with wood paradigm'. Since 3 dry tonnes of wood per hectare is in the ball park for a sustainable world yield, that indicates 2 kW/ha. I mention those energy/land ratios, but I'm sure you realize that it is not the figures which are important. What matters is whether the paradigm has a useful connection with reality.

Having presented those possibilities, Wackernagel and Rees did not actually dismiss their first and third proposals on the grounds that they were unrealistic. Instead they chose the carbon absorption paradigm because: "Many reviewers felt this approach would enjoy the highest public acceptance. It implies no radical shift from fossil fuels yet accepts the need to stop greenhouse gas accumulation." So that is how the problem started: there was never much concern about making the paradigm realistic; also from the very start it was being implied that the paradigm was somehow 'dealing with' the problems of excess carbon emissions. After the *2nd Footprint forum, Part I*, it should be fairly clear to everyone that what it was really doing was serving to conceal the extent of the emissions problem.

*Edmund* Yes, that certainly is apparent now, especially in consideration of the example you gave earlier, of the United States usurping the emission capacity of the whole world. It is a good thing that the 'renewable energy paradigm' is fairly fireproof. I feel there is some hope of getting people to see that the problem of scarcity of fossil fuel energy is not too distant.

*Andrew* I am far from sure how easy it is going to be to make people aware of the need to plan for the demise of fossil fuels. Unfortunately there have been many false alarms. However, I think the science is better now, and most petroleum geologists believe that shortly after the middle of this century our supplies of oil and gas will be about half what they are today, and although coal will still be available, the energy profit ratio, that is the ratio between the energy extracted and the energy needed to extract the coal, will be falling rapidly. It is estimated that the energy profit ratio for U.S. coal, at the mine-mouth, fell from 80:1 in the 1940s to 30:1 in the 1970s.[1]

*Edmund* The other problem is being sure the energy/land ratio is right. I followed your reasoning that 95 GJ/ha/yr is not an excessively optimistic energy/land ratio to use, but I would be glad to see where that figure fits into the whole picture of the energy/land ratios based on the carbon absorption paradigm, as they have evolved in eco-footprinting.

*Andrew* You are right in thinking that the figures used in eco-footprinting have 'evolved'. In *Our Ecological Footprint* a carbon absorption rate of 1.8 tC/ha/yr was accepted as the best available estimate for forest absorption, and the mean carbon/energy ratio — using a mix of fuels — was estimated at approximately 0.018 tC/GJ. Of course 1.8 / 0.018 = 100 GJ/ha/yr, or 3.2 kW/ha.

In *Ecological Footprints of Nations*,[2] the carbon absorption rate for forest was revised downward, on new evidence, to 1.42 tC/ha/yr. At the same time a more *nation-specific* assessment of carbon release was made by taking account of the types of fuel that each nation was burning.

For the world as a whole, calculating according to the mix of different fuel types used, the mean carbon/energy rate is 0.020 tC/GJ. That gives an energy/land ratio of 71 GJ/ha/yr (for a carbon absorption rate of 1.42 tC/ha/yr).

In the *Living Planet Report 2000*,[3] there was a further substantial reduction in the estimated carbon absorption rate, to 0.95 tC/ha/yr. But a new consideration was introduced: because about 35% of our carbon emissions are currently removed naturally, going mainly into the oceans, it was deemed necessary to take account of only 65% of our emissions. The revised carbon absorption rate, taking both factors into account, was 0.95 / (0.020 x 0.65) = 73 GJ/ha/yr, so the change in the energy footprint for fossil fuels was negligible.

*Edmund* In LPR 2002[4] the situation is slightly more complicated, because the energy footprint is broken down into fossil fuel and various other components. What effect does that have?

*Andrew* Not much. Energy-capture for fossil fuels works out at about 73 GJ/ha/yr, as I just said; and for all types of energy taken together, at 80 GJ/ha/yr. The latter figure is higher, I suppose, partly because of the better energy-capture of hydro.

*Edmund* Is the energy-capture of hydro much better than biomass?

*Andrew* Such assessments as are available are not based on very sound data. In primary energy equivalent terms, LPR 2002 uses 1000 GJ/ha/yr, or 32 kW/ha. However, possibly that is too high. Vaclav Smil, in *Global Ecology*, page 187,[5] says the power density of most of the lower-course hydrogeneration, requiring large reservoirs, comes out at "just above 1 $W/m^2$." This is 10 kW/ha = 10 x 31.5 = 315 GJ/ha/yr. From the context, it is clear that Smil is talking in primary energy terms. Pimentel is explicitly talking in electrical terms when he states that a random sample of 50 U.S. hydropower reservoirs require 75,000 ha to produce 1 billion kWh/year of electricity.[6] Changing that into primary energy, the energy capture becomes $(1 \times 10^9 / 0.33) / (24 \times 365)$ = 345,925 kW = 345,925 / 75,000 = 4.61 kW/ha = 4.61 x 31.5 = 145 GJ/ha/yr. Using both those figures, 315 and 145, suggests to me that 250 GJ/ha/yr, or 8 kW/ha, would be in the ball park. That is about 4 times better than biomass.

*Edmund* I mainly asked the question because I wondered how much contribution hydroelectricity might make to achieving the 3 kW/ha of the renewable energy paradigm. From what you say, it is clearly not going to do anything dramatic, especially as hydropower will only be a small part of the whole supply.

Another thing which puzzles me is why eco-footprinters seem mainly to concentrate on results in terms only of *present consumption*, and also without taking *sustainability* into account. Surely what is really important is to use the rough approximations of eco-footprinting to see what the carrying capacity is when all people enjoy the rudiments of a good life, and when agricultural methods are sustainable.

*Andrew* As usual Edmund, you have put your finger on the key point. There are many inaccuracies in eco-footprinting, but they all pale into insignificance beside the changes that will occur as a result of changed lifestyles, and the effects of changing to sustainable agriculture. David Pimentel sees that clearly, as did David Willey and of course many other people in OPT, but surprisingly few eco-footprinters do.

*Edmund* So I think we have thrashed over *Part I* fairly thoroughly. I would be interested to know how *Part II* of the *2nd Footprint forum* is developing. The plan, as I recall it, is to get people to explain their ethical stance regarding sharing out biocapacity. I wonder what ruses people will think up to avoid addressing the question!

*Andrew* I fear that they will be more ingenious at that than we can ever imagine! I have to say *Part II* of the forum is one I embarked on with trepidation. Any discussion on ethical issues is fraught with problems, because the issues are within the realms of psychology, history, and politics, rather than hard science. Yet we must tackle the issue to try to avoid misdirection of effort. There are, as I see it, plenty of voices urging misdirection of effort. None is more vocal than Friends of the Earth. In *Tomorrow's World* the authors appeared to want to create a 'worldwide welfare state'.[7] Matters of ethics are a great problem, in that they are *almost* outside the bounds of reason. Fortunately, though, reason does intrude to the extent that ethics needed to be grounded in the reality of human nature, and I think we can agree that a 'worldwide welfare state' does not accord with human nature.

*Edmund* My guess is that most people will answer either by expressing a general dislike for what they will call the 'selfish' idea of nations living within their own biocapacity, or point out that the rule cannot be made to work in certain cases, such as Singapore, but they will not propose any workable alternative.

*Andrew* I think you are right, and that is one problem I may have to face. Another is that people will want to digress into a discussion of exactly what it means for a nation to 'live within its biocapacity'. In response I will point out, first, that we are discussing principles and not the detailed implementation and, second, that probably the most useful definition of what it means to live within biocapacity is to live within carrying capacity, where carrying capacity has the meaning defined on the front of *The Pherologist*: "Pherologists define carrying capacity as the human population that can be supported in a given territory, in a specified lifestyle (normally the one to which people may reasonably aspire), without degrading their physical, ecological and social environment, and without imposing wastes on the global environment beyond a specified (or internationally agreed) limit." To be honest, I see *Part II* of the forum being similar to *Part I*, insofar as the truth of the matter is perfectly obvious, but it still requires an overwhelmingly clear exposition of the situation in order to get people to change their preferred way of looking at things.

## Endnotes

1 Gever, J., R. Kaufman, D. Skole, and C. Vörösmarty. 1986. *Beyond Oil:The Threat to Food and Fuel in the Coming Decades*. Niwot, CO: University Press of Colorado.

2 Wackernagel, M., Onisto, L., Callejas Linares, A., López Falfán, I.S., Méndes García, J., Suárez Guerrero, A.I. and Suárez Guerrero, M.G. 1997. *Ecological Footprints of Nations*. Centro de Estudios para la Sustentabilidad, Mexico. 32 pp.

3 WWF, 2000; World-Wide Fund for Nature International, UNEP World Conservation Monitoring Centre, Redefining Progress, Center for Sustainability Studies. *Living Planet Report 2000*. Ed. J. Loh. Ecological Footprints led by M. Wackernagel. WWF, Gland, Switzerland. (32 pp.).

4 WWF, 2002 — update of previous; 36 pages.

5 Smil, V. 1993. *Global Ecology: Environmental change and social flexibility*. London and New York: Routledge.

6 Page 206 of Pimentel, D. and M. Pimentel. 1996. *Food, Energy, and Society*. Revised edition. Niwot Co., University Press of Colorado. 363 pp.

7 McLaren, D., S. Bullock, Y. Nusrat. 1997. *Tomorrow's World*. London: Earthscan.

Motives for irrational thought are an interesting subject of study. I can recommend a book by Rupert Crawshay-Williams, written in 1947, titled *The Comforts of Unreason: a Study of the Motives behind Irrational Thought*. In reviewing it, Bertrand Russell said, "In his book, Mr Crawshay-Williams deals with the various tricks and devices, conscious and unconscious, by means of which we persuade ourselves that things are as we should wish them to be — or persuade others that things are as we wish those others to believe them to be." In the following review, Jill Curnow provides us with a penetrating insight into the tricks and devices used by a professor of statistics, who appears to be following in the footsteps of the late Julian Simon (professor of marketing) in producing material which good scientists have to spend time deconstructing. They have done just that, but no one, I think, has unravelled the deceptions with a lighter and more amusing touch than Jill Curnow.

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## BJORN LOMBORG, SPIN DOCTOR EXTRAORDINAIRE

By Jill Curnow, Vice-President of the NSW branch of Sustainable Population Australia.

Bjorn Lomborg's *The Skeptical Environmentalist* was published by CUP in 2001. The book decries the "Litany of our ever deteriorating environment" (p. 3) and declares that "Things are getting better" (Chapter 1). Since publication there has been a chorus of dismay from environmental scientists and activists. This response is understandable, yet the work is carefully considered, well written, contains 352 pages of text, 2930 footnotes, 70 pages of bibliography and it was reprinted seven times in its year of publication. Not a book to dismiss as a trifle.

Lomborg makes some excellent points. He draws attention to the large amount of "bad news" on the environment and notes that those who present this bad news may have become carried away with their cause or may have reason to present a dismal picture. If the environment appears in bad shape then biological scientists may find funding easier to obtain, environmental organizations may gain more members and prestige, and newspapers may sell more copies.

*The Skeptical Environmentalist (The S.E.)* describes techniques that can be used, consciously or otherwise, to massage the facts so they support a certain point of view. The work continually draws attention to environmental misinformation which has resulted from such techniques, and to this point the book is invaluable. Unfortunately the author then falls into the same errors for which he so criticises others, and the author uses identical techniques to 'prove' the opposite case.

The volume is designed so it can be used as a textbook. It would be invaluable in this role, not only because of the environmental information it contains, but because of its extraordinary use of debating techniques. Anyone who wants to argue a case that is scantily supported by the facts, or persuade others that the facts are not as they appear, should study the techniques used in this book. Some of them are:

**Ignoring sources that do not support the preferred viewpoint**. For example, many studies have examined the energy input/output ratio of wind turbines. Some give favourable ratios, some do not. *The S.E.*, while assuring us that energy is plentiful, quotes only one — that given by an association of turbine manufacturers (p. 125), and thus presents a very favourable ratio without mentioning that there are differing views.

**Stressing the irrelevant.** A false impression can be achieved by basing an argument on a fact of little relevance. For example Chapter 13 "Water" places great stress on the abundant quantities of fresh water on the planet, and suggests that water scarcity can be due only to the amount of money (p. 155) to build infrastructure. The problem with water is not its planetary scarcity but the huge quantities we utilise (about one tonne per person per day) and the difficulty of transporting water to where it is needed. The fact that Iceland has lots of water is not much help to someone who wants to irrigate corn in Nigeria or wash his hands in Alice Springs. *The S.E.* fails to note that the money and resources needed to transport millions of tonnes of water around the planet make such projects unrealistic.

**Omitting inconvenient facts.** For example, the section on planetary supplies (pp. 106-108) claims that these will not fail because fish farm production will replace the wild catch. The book fails to note that fish in farms must be fed and often they must be fed fish. Whatever they consume, it is food that is not available for humans. Fish farms feed cheap food to breeds of fish that are popular with wealthy consumers and thus they make money, but they do not increase the human food supply. *The S.E.* provides an optimistic, convincing, but false account of future fish supply by omitting one vital link in the chain.

**Nostradamus. The prediction of others are shown to have been faulty but the predictions of *The S.E.* can be relied upon.** The book constantly draws attention to predictions, made by learned persons over the last fifty years, which have proved to be inaccurate. So much space is devoted to this that one would expect the author to be very cautious about the art of foretelling the future. However, *The S.E.* confidently states "no serious problems for the continued growth of production and welfare are in the offing" (p. 211); "food production will continue to give more people more and cheaper food. We will not lose our forests; we will not run out of energy, raw materials or water" (p. 329); and "the world is basically headed in the right direction" (p. 351).

**Sweeping, unsubstantiated statements.** Chapter 23 on biodiversity devotes several pages to statements by scientists and environmentalists regarding biodiversity loss. The book claims many of these statements were made without sufficient data to support them and the author is rightly critical of such practices. However *The S.E.* then claims that "practically no extinction has taken place" in "the developed part of the world" (p. 256). No evidence for this astounding statement is offered. Once again, *The S.E.* has used a technique it condemns in others.

**Displaying sweet reason and calm consideration towards the point of view of others while using questionable means to discredit those views.** For example, on pp. 13 and 14 *The S.E.* condemns Worldwatch Institute for referring to "record rates of population growth" in a report in the year 2000. The author notes that rates of population growth peaked in 1964 or 1990 according to the statistical method used, and declares that Worldwatch Institute was "just plain wrong" (p. 14). However *The S.E.* itself refers to the "massive growth in the world's population [which] began around 1950 and will probably end around 2050" (p. 45). At worst, the statement by Worldwatch may have been carelessly phrased. *The S.E.*, while appearing entirely reasonable, attempts to discredit Worldwatch over a statement on which there is basic agreement.

**Ignoring inconvenient arguments.** Lomborg is ignorant of, or chooses to ignore, the concept of ecological footprint, which is the area of land required to support an individual or community at a certain level of consumption. He appears unaware, for example, that cities need a huge area outside their borders to provide them with food, water, energy, waste disposal and other needs (p. 49). He is also unaware that population density is virtually irrelevant in an assessment of population carrying capacity (p. 48). He believes that as the developing world gets richer it will be able to preserve its environment better, not realising that as a population gets richer its footprint increases (p. 256). Were Lomborg to acknowledge the ecological footprint of each of us many of the arguments in his book would collapse.

**Internal inconsistencies.** Some statements in the book reveal the flaws in arguments elsewhere. For example water in dams is claimed to be able to provide for extra water needs in the future (p. 157) and to provide electricity when the sun does not shine nor the wind blow (p. 135). However these rosy predictions are undermined on page 131, which notes that dams have "negative consequences for the environment" and the fact that "most dams silt up within 20 to 50 years."

The above list does not do justice to *The Skeptical Environmentalist*. There are more techniques, some too complex to be discussed in a brief review such as this, and each technique is used repeatedly, though for the sake of brevity only one example is given for each. Some sections intertwine various techniques in a rich tapestry (for example Chapter 11, "Energy") and thus paint a false picture. The volume deserves to become a spin doctor's manual.

## Population

The chief concern of Sustainable Population Australia Inc. is the achievement of an ecologically sustainable population size. Lomborg declares that "the number of people is not the problem" (p. 48), and uses various statistics to 'prove' his case. He 'succeeds' by using the techniques described above and also by accepting an intolerable standard of living for most of humanity. Lomborg, like you and I, enjoys regular access to a telephone, computer, hot shower, motorised transport, educational and health services while living in a secure dwelling. None of us would be content without these conveniences, yet *The S.E.* expresses satisfaction with the world provided people are not actually starving, describing life where there is merely enough to eat as "a decent existence" (p. 101). The developing world apparently should be satisfied with "better access to clean drinking water," while the developed world might seek "better retirement homes [and] kindergartens" (p. 6). *The S.E.* adopts an extraordinarily low standard for poverty, declaring "there are still 1.2 billion poor people" (p. 330). Were the poverty line to be drawn at the point where readers of *The S.E.* would find life tolerable, then the number living in poverty would be 4 or 5 billion, and it is doubtful if even Lomborg, with all his skill, could look at the situation through rose coloured glasses.

**Further reading:** Other reviews and critiques of *The S.E.* can be found in *The Scientific American*, issues of the early months of the year 2002, (including a response from Lomborg), in *Pacific Ecologist* of March 2002, in *Population and Environment*, Vol 23, No. 4, March 2002, and on the Australia Institute website <www.tai.org.au>. Lomborg has his own website, <www.lomborg.com>.

THE END