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Propelled by government incentives in Germany and Japan, as well as a number of U.S. states, sales of photovoltaic silicon panels have soared, helping drop manufacturing costs and leading to product refinements.

Vinod Khosla, a prominent Silicon Valley entrepreneur focused on energy, said the market-driven improvements were not happening fast enough to put solar technology beyond much more that a boutique investment. "Most of the environmental stuff out there now is toys compared to the scale we need to really solve the planet's problems," Khosla said.

Andrew Revkin and Matthew Wald in the New York Times, 16 July 2007

The Optimum Population Trust (UK): Manchester

<www.members.aol.com/optjournal> & <www.optimumpopulation.org>

INTRODUCTION

Ten pages are given in this issue to Martin Desvaux's synopsis of Clive Ponting's *A Green History of the World*. This is slightly longer than usual, but Chapters 12 and 13 are especially important. Chapter 12 brings home the damage caused by increasing human numbers both to humans themselves and to other aspects of the environment. Chapter 13 focuses on another matter of great relevance to an optimum population, namely energy supplies. Up until 1900, all energy was provided by humans, animals, wind and water. But now, about 90% comes from fossil fuels.

Every two years WWF and the Global Footprint Network publish a superbly produced booklet titled *Living Planet Report*. The idea is to assess the increasing damage that humans are doing to the rest of the natural world, with the Footprint section of the booklet measuring the ever increasing impact of humans. However, rarely is attention drawn to the impossibility of allowing everyone to enjoy a decent lifestyle while there are so many people on the planet. On pages 13-14 David Nicholson-Lord brings out some vital conclusions about sustainable population sizes derived from the *Living Planet Reports*.

Pages 15-19 draw from Lindsey Grant's recent 52 page booklet, *The Age of Overshoot*. The particular chapter we choose here is titled *Economists' Myths*. It is a fine summary of one of the themes that recur in the OPT Journal, namely the lack of realism in the thinking of the great majority of economists (with their belief in perpetual growth), and the politicians who follow them.

One great problem of using biomass as an energy source is the low power density achieved. The realization of this is slowly dawning in the press, but only slowly, and on pages 20-24 the limitations of ethanol from sugarcane grown in Brazil are considered.

Page 25 is a commentary on an excerpt from a Canadian newspaper. It brings out the important point that politicians delude themselves about the prospects for renewable energy rather than confront the problems described by Lindsey Grant; and it plausibly suggests that nothing else may be possible in a democracy.

William Stanton, author of *The Rapid Growth of Human Populations 1750 — 2000*, is certainly under no delusions about the problems of living without fossil fuels. His explanation of the value of machinery in agriculture provides a good lead into his updated population graph on page 27. It is chastening, as one looks at his graph, to realize that humans are on course to release in four hundred years a considerable proportion of the carbon that was stored in over 400 million years.

A recent study by the Oswald Consultancy of the potential for wind power in the UK should be a model for all such studies. As the commentary on pages 28-30 makes clear, the limit for this particular uncontrollable, wind, is to supply about 20% of electricity demand, and other uncontrollables cannot be of much assistance. Page 31 shows why PV is only occasionally a useful adjunct to wind power.

The graph on page 32 is an update of one first shown in 2001. The change in the projection of a population of one billion in the USA — now projected to be reached by 2075 rather than 2100 — is an indication that those who have been crying wolf about the expansion in the U.S. population have been doing so with good reason.

I am very grateful to Walter Youngquist for the material he sends me, some of which appears in this issue. Martin Desvaux and David Gosden have helped me get my pieces into shape. Somehow David Pimentel finds time in his busy schedule to peruse and make useful comments on my work. Thanks finally to Yvette Willey, both for practical assistance with the mailing labels to send out this journal, and for applying her remarkable skills as a proof reader.

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CLIVE PONTING'S *A GREEN HISTORY OF THE WORLD*

A synopsis by Martin Desvaux PhD CPhys MInstP
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> ***"****There is so great a scarcity of wood throughout the whole kingdom ... the inhabitants in general are constrained to make their fires of sea-coal or pit coal, even in the chambers of honourable personages.****"***
>
> *Stows Annals 1631*

Introduction to the Fifth Instalment

In Chapter twelve, Clive Ponting depicts the inexorable ascent of humanity. He provides a quasi 'fast forward' satellite view of mankind's history from the perspective of the pressure to which growing populations impact upon the planet. In Chapter thirteen, the reader cannot fail to appreciate the latent message that wood is our most versatile resource – ever. Without the need for chemical processing, it is used for building, decorating, making, burning, containing, relaxing, hunting, cooking, transporting and perhaps finally, interring. It is embedded in every aspect of our life and, given but half a chance, it is renewable. Its welfare is the bellwether of humanity. That is why, when reading these chapters, one cannot help but regret how we and our recent ancestors, for the most part ignorant of the consequences, have treated the stuff by deforesting on a grand and global scale. The despair hits hidden depths when Ponting describes how we, in particular, are continuing the practice. While preparing this instalment, I found it difficult to resist the guilt trip, to go out and buy a few acres of woodland, convert the back garden into a copse and club seven bells out of anyone with a chainsaw coming in my direction!

Enough emotion! It is the big picture, seasoned with statistics, which is the power of this book and comes out strongly in these chapters. However, do bear in mind that in relation to all the contemporaneous statements, you are reading this in 1990 and *not 2007*. I was tempted to update the figures and some statistics and have almost entirely resisted that urge. Nevertheless, the occasional [square brackets] show where I have tweaked a bit. To have done so extensively would have pre-empted Clive Ponting's excellent rewrite entitled: '*A New Green History of the World'* which updates the original and has just been published this May. Although I have not yet had time to read it from cover to cover, what I have read indicates that it is even better than the original which is the subject of this work.

Chapter 12: The Weight of Numbers

The explosion of populations[1] is the greatest change occurring in our history. The world population reached 1 billion in 1825, reaching five billion in 1988 [and 6.6 billion in 2007]. The time spans to add a further billion to the planet has shortened from 100 years (1825 to 1925) down to 12 years (1975 to 1987) but rates of growth varied by continents and by region.

Year	**1700**	**1900**	**1990**	**2006**
World	610	1700	5000	6600
Europe	120	450	630	730
Asia	415	970	2300	2660
China	150	450	1000	1314
India	150	290	750	1095
Africa	61	110	400	910
United States	6	76	220	300
Oceania	2	--	23	33

Table 1: Some Key Population Statistics since 1700

In Europe, growth was initially slow but it gathered pace during the 18th and 19th centuries to reach 450 million by 1914.

Had it not been for the mass emigration to the New World, Europe's population would have been over 40 million higher. After 1914, the growth rate lessened to 3/7ths of the rest of the world. Regional variations were large. Ireland's population partially collapsed between 1850-1900 because of the potato famine and the subsequent flood of emigration.

In Asia, the growth was more dramatic. Already at 450 million in 1750, population doubled to 970 million by 1900 before attaining 2.3 billion by 1990. China's population – 150 million in 1700 – reached one billion in 1990 [*and 1.31 billion in 2007*]. The population increase in Africa has been one of the highest in recent times. The 60 million people in 1700 almost doubled to 110 million over the two hundred years to 1900; it then *quadrupled* to around 440 million in the next ninety years. [*It more than doubled over the next 17 years to around 910 million in 2007*]. Due to high initial immigration combined with a natural increase, the population of the United States, being only 6 million people in 1800, had grown a century later to 76 million and then to 220 million by 1990 [*300 million in 2007*]. To complete the picture, Oceania with around 2 million people in 1850 had increased to 23 million in 1990 [*33 million in 2006*]

"*The fact that the earth now supports five [2006: six] times as many people as 200 years ago seems, at first glance, to be a triumph of human ingenuity in getting round the limitations on food supply that had … restricted the growth in human numbers to very low rates. However … the impact on the environment of these changes has been profound*."

The ability to feed the rising populations was due to a number of developments[2]. In Europe and China the traditional response had been to bring less fertile land into the agricultural sphere. Due to its world influence resulting from colonial expansion,[3] Europe was able to obtain the extra food supplies from its colonies. However, these extra supplies would have remained limited, had it not been for the combined effects of four other technology-based developments. Firstly, in the mid 19th century, railways enabled more rapid access to ports from inland plantations and farmlands whilst steamships provided faster ocean transport for perishable cargoes. Secondly, the latter part of the 19th century saw innovations for chilling and refrigerating cargoes, which could retain their freshness over longer voyages. These developments caused a fifty-fold increase in international food trade from 4 million tons in 1850 to 40 million tons by 1914 after which they remained steady until 1950, before increasing five-fold to 200 million tons in 1980. The result of these changes was that, whereas prior to 1850 all Europe's imports were luxury goods, after that point they were gradually dominated by grains, meats and dairy goods. "*European countries, especially Britain, became dependent on imported food in the late nineteenth century. In the years immediately before … 1914 Britain imported 80 per cent of its wheat consumption, 65 per cent of its fruit and 40 per cent of its meat*." Thirdly, gradual improvements in crop productivity made a significant contribution to the food supply. Between the 13th and 19th centuries crop yields had doubled but, after that, the seed drill and (from the 1840s) tiled underdrainage, better animal feed (oil cake) and mechanisation resulted in significant growth. Post 1850 mechanisation – in part stimulated by labour shortages – and the use of artificial fertilisers (guano, super phosphates and nitrogenous salts) were two further factors which greatly increased production. The significant impact of these can be seen from just one example: "*Greater mechanisation made it possible to increase farm size ... in the United States the number of farms fell from 7 million in the 1930s to below 3 million in the 1980s and over half of all sales of agricultural produce came from just 5 per cent of the total number of farms. … The paradox of modern agriculture in the industrialised world … is that, as the output has soared, the number of people working in agriculture has plummeted, with major implications for society and the countryside*."

The fourth development was improved animal productivity. Early domestic animal production was extensive and was limited by available grass and winter fodder and selective breeding. In the 20th century it became intensive, bringing animals indoors and feeding them on a diet which could include dead animals, recycled manure and growth hormones as well as antibiotics to control diseases that could emanate from such food. Increasing numbers of salmon farms became established and by 1990, 25% of British fish were being farmed. Government subsidies were used to keep prices above the market rate in the United States and in the European Community, a practice which resulted in massive surpluses of many crops. By 1990, subsidies in the UK amounted to 40% of production.

As technology influenced and changed farming methods, it had a contemporaneous impact on the food processing industry which traditionally consisted of bread, pies and jam since all produce was eaten fresh and consequently had limited availability in towns. A major development occurred in the dairy industry. Pasteurisation together with faster transportation and new ways of keeping produce cool combined to cause rapid expansion. *"In 1861, just 4 per cent of the milk sold in London came by rail but thirty years later it had risen to 83 per cent. By 1914 much of the milk sold in New York came from over 300 miles away and in the 1930s most of the milk supply for Berlin travelled more than 400 miles. ... [in 1990] milk constituted over a fifth of the total agricultural output of the United States and the European community."* Later, canning and refrigeration enabled vegetables and fruit to be consumed out of season and country of origin. The growth in the processing industry meant that farmers only got between 4 and 17 percent of the price of many of the foods sold in the shops. During the early days of food processing, many of the foods were adulterated and barely fit for consumption, resulting in a wide range of Government legislation to protect consumers against unscrupulous profiteering. Such practices still occur even today.

The development of farming in the Third World countries over the last 200 years is really a story of how self sufficiency for peasant farmers was replaced by unequal land distribution on a massive scale in order to increase crops grown almost entirely for export. For instance, in Africa 75% of the population owned only 4% of the land. This was exacerbated post WWII by the introduction of more productive varieties of wheat (in Mexico) and rice (in the Philippines). Termed the '*Green Revolution'*, this intensified the gap between rich and poor farmers since the new strains required more fertilisers and pesticides than conventional crops putting them beyond the investment capabilities of small peasant farmers. The richer farmers who could afford these inputs became wealthier and bought up more land from the bankrupt peasants.

The drive for exports meant that indigenous Third World countries became dependent on the world markets for their food. And many of them producing food for export eventually became net importers. As Ponting points out: "*The agriculture of the industrialised world is not necessarily more efficient than that of the Third World – what it is able to do is purchase more inputs and therefore ensure higher output. In energy terms it is actually less efficient. Overall there is enough food in the world to feed everybody at an adequate level – the problem is its unequal distribution… More food is sent from the Third World to the industrialised countries than in the opposite direction ... a large proportion of this trade has been to provide more variety in the diet of those who are already well fed.*"

Famine, once prevalent in Europe, died out in the 18th and 19th centuries. Not so in the Third World. "*In none of the twentieth century famines has there been an absolute shortage of food; the problem has been unequal access due to poverty, a problem that resort to food aid has not solved.*"

As a result, when world prices soared, people in countries with plenty of food have died in their hundreds of thousands. "*In Bengal in 1943-1944 about three million people died after rice prices quadrupled in two years ... In Ethiopia in 1972-1974 about 200,000 people died ... even though the country's food production fell by only 5 per cent ... In Bangladesh in 1974 when rice prices doubled in three months after severe flooding, one and a half million people died of starvation ...when production of rice in Bangladesh was the highest ever ... [because] it was a problem of who had the resources to buy food at the higher prices.*"

During the last 130 years, over 800 million hectares has been put under the plough and the cow to feed a growing world population. Unsurprisingly, it has had a tremendously negative impact on the world's ecosystems through "*deforestation, ploughing up of grasslands ... [*cultivation*] of marginal land and steep slopes with a consequential increase in soil erosion, degradation of land and in many areas the extension of deserts.*" In Britain we have destroyed over half of our lowland meadows, heaths and ancient woodlands, bogs and wetlands in the 45 years after WWII. Worldwide, loss of wetlands to agriculture has been a major impact, particularly in the USA where 50% have disappeared, much of that in the Florida everglades where drainage began in 1883 to house people and to clear land for sugar plantations. There, the terraforming achieved by clearing rivers and building canals extensively upset the local ecosystems: "*The water table fell by over two feet, sea water flowed in from the ocean, the main lake was affected by eutrophication (excessive plant growth resulting in the death of animal life through lack of oxygen), peat dried out and the land fell by one foot a year. Most of the wildlife including 90 per cent of the two-and-a-half million wading birds, died out.*"

Table 2 summarises the extensive deforestation that has been taking place over the centuries; we can see that most of that has taken place in the last 150 years at an accelerating pace to provide agricultural land for an exploding world population. Destruction of tropical forests is only a short-term palliative for insufficient farmland. Most nutrients are held in the trees rather than the soil and they are destroyed with the tree, leaving a legacy of poor quality soil. This soil degrades quickly due to wind and rain. Settlers grew corn for a year or two after which large ranchers bought them out for pasture land; after a further five years, when soil was unfit even for that –"*nearly all the ranches established in the Amazon area before 1978 had been abandoned by the mid-1980s. It is a striking example of how quickly a highly productive natural ecosystem can be transformed into an unproductive, artificial one.*"

Country	Period	Deforestation (ha)	Comment
China	1950-1980	20 million	
Rajasthan/Punjab	2000 years	24 million	Thar desert created
New Zealand	1870 -1980	50%	To create sheep grazing
Haiti	200 years	90% cleared	Poor quality topsoil
USA	1790-1850	96 million	Eastern Seaboard
	By 1990	225 million	94% of forests
Worldwide	1980	10 million p.a.	Annual destruction rate
Africa	1980	7 million p.a.	ditto
Algeria	1890-1940	500,000	Food production
World	By 1950	50% deforested	

Table 2: Deforestation in Various Areas of the World over the Last 2000 Years

The practice of monocropping and overgrazing coupled with deforestation and ploughing-up grasslands has led to severe problems with soil erosion; an estimated 15 billion tons of topsoil are lost annually from just half of the world's croplands. Haiti has no quality topsoil left and many parts of Europe (e.g. Massif Central) suffered extensive soil erosion over the centuries. During medieval times, when land was relatively plentiful due to low population density, exhausted soil was left, and eroded, as new areas were tilled. In modern times, the loss of hedgerows on the altar of high productivity caused extensive soil loss, not only in the USA and the Soviet Union but also in Britain.[4] In the USA, because land was freely available, settlers "*paid scant attention of the need to preserve soil quality*." After two years, tobacco and cotton crops, extremely demanding on nutrients, had to be followed by wheat which itself was viable for a further five years. Settlers then cut down more forests and started all over again, leaving the exhausted soil to be eroded by the weather. "*By 1817 in North Carolina the amount of abandoned land was equal to that under cultivation ... [in] the United States area after area was ruined in the space of a few years and then abandoned but the same destructive practices continued in the newly cultivated areas*." With the development of the steel plough it became possible in the late 19th century to cultivate the Great Plains. Despite the experience of previous centuries, the US Bureau of Soils claimed … in 1909 that, "*the soil is the one indestructible, immutable asset that the nation possesses. It is the one resource that cannot be exhausted; that cannot be used up*." Famous last words! After continuous overexploitation of the land, the worst ecological disaster in history occurred in 1934 to create the 'dust bowl': "*In March 1935, five million acres of wheat were destroyed by dust storms, and by 1938, 10 million acres of land had lost the top five inches of soil and another 13.5 million acres the top two and a half inches*." The damage didn't stop there. "*By the 1970s a third of the topsoil of the United States had been lost and nearly 200 million acres of cropland had been ruined or made highly marginal for cultivation.*"

In the USSR, the 'virgin land' programme ploughed up 100 million acres of grassland between 1954 and 1960. Production peaked after two years and declined thereafter when soil erosion proceeded at catastrophic rates with up to 17 dust storms per year occurring in parts of the Ukraine. For similar reasons, soil erosion and dust storms were also prevalent in Australia and China; in the latter, 1/7th of land area is affected and Chinese dust can be detected in Hawaii!

Downstream effects of deforestation and soil erosion are silted up dams and river mouths with consequential high risks of flooding, as in Bangladesh. In many areas, soil erosion progressed to desertification (defined as the permanent loss of land for cultivation), e.g. south west United States, Africa (most notably, the Sahel and Sudan), Chile, Mexico and Australia. Pressure to produce food had also demanded irrigation; between 1800 and 1980, land area under irrigation grew from 20 million to half a billion acres – about 15 percent of the earth's arable land. This has led to waterlogging, salinisation and aquifer depletion: "*Overall, more than seventy million acres of irrigated land has been ruined and the adversely affected area is increasing by about three-and-a-half million acres per year*." The most extreme ecological consequence of irrigation has been the almost total loss of the Aral Sea in the Soviet Union by diverting 'feeder' rivers to water 18 million acres of cotton plantations. This caused salinity of the sea to treble, a lowering of the water table and collapse of the sewage system, "*…(typhoid rates rose twenty-nine fold) and 90 per cent of the children were diagnosed as being permanently ill. In 1990 an outbreak of plague led to the area being quarantined. The Aral Sea and the surrounding area is now the scene of one of the greatest of all ecological catastrophes.*"

Chapter 13: The Second Great Transition.

"*The second great transition in human history ... involved the exploitation of the earth's vast (but limited) stocks of fossil fuels, a move that made possible an era of abundant energy for part of the world's population*." Put simply, energy is needed for lighting, cooking and heating, and after that, to perform tasks in agriculture, transport, construction and manufacturing. Historically, energy in the form of wood, coal, wind and water was constrained by local availability, until the development of electricity in the early 19th century. Initially, the scope of productive activity was limited to human energy and mainly to the hours of daylight. Until the late 1800s, human labour was used extensively; in the 15th century, the Great Crane of Bruges was powered by a human treadmill; in the 19th century industrialists could buy energy from human treadmills in British prisons (hmmm…!); until the 20th century the main source of household energy was servants, "*As late as the first decade of this [20th] century two-and-a-half million people (84 per cent of them women) were employed as domestic servants in Britain and they constituted the largest single occupational category."* [5]

Historically, the problem of mobilising large quantities of labour to build world wonders was solved by either subjecting large numbers of the population to forced labour or by using prisoners-of-war and other people from conquered lands as slaves. China provides us with two outstanding examples: *"... the building of the Great Wall involved about 1 million workers, of whom died half during the work. The construction of the Grand Canal, to bring food to the capital Peking and the armies in the north, used about five-and-a-half million workers guarded by 50,000 police and again about half of the workers died on the project.*"

Slavery[6] was normal in the early societies. The great states of the ancient world used them for agriculture and domestic work, while Europe later on used them on plantations to provide exportable cash crops. Most societies have used human labour for transport from carrying sedans to rowing triremes and even today in the Far East [and London!] for transportation by rickshaw.

Animals also provided a source of labour. The main downside of using animals was the need to feed them (horses require five acres each) on land which was also needed to feed humans. They were, however, useful for carrying heavy loads over long distances. Asses, onagers, mules, oxen, horses, camels, and dromedaries all found their niche the latter being particularly suited to hot desert climates. While all have been replaced in advanced countries by mechanised vehicles, many are still extensively used in the Third World where such wheeled transport is generally unaffordable.

Wheeled transport dates as far back as 3500 BC in Mesopotamia and a little later in Egypt and the Indus Valley. Horses, domesticated around 3000 BC were used predominantly for riding and did not become useful draught animals until around 800 AD when the traditional ox harness, which tended to choke them, was replaced with a more suitable design. That, and the development of horseshoes around 900 AD, transformed the horse into a ubiquitous source of energy for agriculture, transport and industry such that: "*Joseph Arkwright [developer of textile machines] used nine horses at his first factory in Nottingham to power 1000 spindles*". By the 18th century, twenty-four million oxen and 14 million horses were the main draught animals in Europe and the Near East.

The horse was also widely used for warfare. Warhorses were bred for the job. Early applications included the onager-drawn chariot, then the cavalry. Feeding them was always a constraint. Nevertheless, "*During the First World War, the British army used 1,200,000 horses and in the Second World War the German army had mechanised Panzer divisions but it also required the logistic support of 2,700,000 horses.*"

By about 1800, horses and oxen were generally replaced by steam power in such applications, but remained vital for transport (carriages, barges, railways, etc) until well into the early part of the 20th century. As the railways became established, more traffic was generated and could only, until the development and affordability of the motor car, be satisfied by horse drawn carriages. "*In 1810 there were about 15,000 privately owned carriages. The number increased to 40,000 by 1840 and to about 120,000 in 1870. ... The number of horses kept in towns for private and business traffic rose from about 350,000 in 1830 to 1,200,000*[7] *in 1900 ... As late as 1913, 88 percent of London's goods traffic was still horse drawn. At the start of the twentieth century Britain had a horse population of about three-and-a-half million (about twenty-five times the current level).* "

Such large horse populations needed to be fed and competed with the needs of the human population. Their 'fuel' of oats and hay came from 15 million acres of cropland, which was only possible due to cheap imports.[8] (In the United States, the figure was 90 million acres!). Once motorisation of transport took hold, the horse population declined until by 1990 it was around 140,000.

Water was first used, in Egypt, to power irrigation works and a grain mill in 100 BC. These 'utilities' subsequently spread throughout Europe over the course of several centuries. The scale of their popularity was evident from the Domesday Book, which, in 1086, recorded 5,624 mills (mainly for grinding grain) in 3000 settlements in Britain. Whilst it saved labour, it was not without problems from variability of river flows, being frozen in winter, reduced during dry weather and suffering from other water wheels in their vicinity – thus weakening their supply. Water mills started to revolutionise industry from the 12th century and continued to be built until the 19th century. Their first use was for fulling cloth around 1086 in Normandy, then for tanning leather around 1138 in Paris and for papermaking in 1238 in Valencia. Additional uses included making mash for beer, sawing, operating bellows and grindstones, and later in the 16th century for milling coins and polishing precious stones. Although water mills were powered by rivers, a limited number of tidal mills were established – one notably in the Adriatic near Venice in 1044 as well as a few in Devon and Cornwall for corn grinding – but these never really caught on. The industrial revolution saw an increase in water mills in Britain particularly along the banks of northern rivers. They were also used to power London's water supply in the 19th Century; in 1900, Nuremburg had over 180 operating mills; in Japan, steam did not take over from water until the 1890s; in the United States, industries depended entirely on water power until the 1880s.

Wind provided a complementary power source to water. Although it had the advantage of being able to work when water froze over, this was partly offset by the inconstancy of the wind. Windmills were first developed in China and Tibet as prayer wheels but were used for industrial power by the late 13th century. They were developed independently in England in the 12th century and spread out from there across Europe. Their success can be seen by the fact that, in the 18th century, the Netherlands had over 8000 windmills being used for a host of applications including drainage of cultivation areas.

Until the exploitation of fossil fuels, wood was the prime source of energy. Locally available and renewable, when dried or aerobically converted into charcoal, it was used for all the heating, building, manufacturing and transport needs of humans. Because of its abundance, the fact that it was renewable was virtually ignored; a by-product of deforestation was that another necessity – land for living and food production – was automatically increased. "*A moderate-sized house in medieval England required a dozen oaks to be cut down and … work on Windsor castle resulted in the felling of 4000 oaks in ten years … Hopewell [blast] furnace in Pennsylvania was using up as much as 750 acres a year*." Such wasteful consumption of what was to become a diminishing resource is illustrated by the fact that, one works in Russia was using 1,000 tons of wood for each ton of potash produced and, *"By 1662 Russian potash production was using up a total of three million tons of wood per year*."

Wood shortages first became apparent in the fifteenth century as a result of the extensive shipbuilding industry in Europe. Venetians exhausted local supplies and by 1590 they "*had to import completed hulls for their ships*." In the 16th century, Portugal had to build most of its ships in its colonies; Spain imported wood from Poland. In England during the mid-1600s, shortage of Sussex oaks for 120 ft mainmasts forced the Admiralty to replant belatedly (it would take 100 years for these trees to mature) whilst importing from Scandinavia and Russia during the interim. The Royal Navy then resorted to building its ships in North America until the American War of Independence and Napoleonic wars forced it to import from Canada.

"*A shortage of timber for naval construction was only one symptom of a major problem affecting the whole of Europe. … widespread shortage of wood meant that Europe faced an energy crisis*." This impacted on downstream industries, for example: some Slovakian iron foundries had to cut back on production; French bakers had to burn bushes in their ovens to bake their bread; the poor could no longer afford fires and a Polish salt evaporation works, which used wood as the source of heat, closed down in Wieliczka.

In Britain, the crisis deepened throughout the 16th and 17th centuries as charcoal prices rose dramatically such that "*in most areas of the country blast furnaces were only able to operate in short bursts every few years*." The result was that, begrudgingly, people gradually resorted to use what was viewed as an inferior fuel, namely coal. But when needs must, the devil drives and, starting with the poor, 'pauper coal' was used first by the poor and later by the rich so that the long reign of 'King Coal' began.

Coal had been used in small amounts in Europe for centuries, but more serious exploitation began to take off in the 16th century and marked the beginning of our dependence on non-renewable energy. First the shallow pits were mined, but later the rising price of charcoal made deeper mining economically viable. The result in terms of world output was dramatic: by 1800, 15 million tons (Mt) were being extracted; by 1860 this rose by almost an order of magnitude to 132 Mt; and then by more than five-fold to 700 Mt by 1900. *"… from a negligible contribution, coal came rapidly to account for 95 per cent of the world's energy consumption*." As a by product, waste gases from coal were used for lighting. In the United States, lower population and an abundance of forest wood meant that the transition to coal did not happen until late in the 19th century.

The most significant development of the 19th century was the production of highly convenient electrical energy, from fossil fuels. Electricity generators were first made in London in 1834, and by 1875 the first commercial lighting application was installed in the Parisian Gare du Nord. The invention of carbon filament lamps (1881) was followed by more reliable tungsten filaments in 1911, and this advance boosted the use of electricity for lighting applications. As applications increased, industrial and domestic usage spread, leading to the development of national grids. As a result, power-plant sizes increased from 30 MW average in the 1920s to 600 MW by the 1970s. Europe's dependence on energy from coal peaked early on in the 20th century, declining from 90% at the start to 30 % by 1970, as cheap oil became increasingly attractive.

Oil had been known about for centuries. It seeped through the earth's surface at several locations, but was not commercially produced until 1859 at Drake's well in Pennsylvania. By the 1890s, 85% of oil produced was used in the form of kerosene, for lighting as a substitute for whale oil which was by then becoming scarce due to whales being hunted to near extinction in many areas of the world. In the early 20th century, furnace fuel-oil accounted for 50% of production. After the development of the internal combustion engine, gasoline then became the main refined product by 1930, followed by aviation fuel. Cheap oil did for economic growth in the 20th century what coal had done in the 19th century. Annual production, around 10 million tons in 1890, reached 2500 million tons by 1970. In America, *"…oil consumption increased at an average rate of 9 per cent from 1890 to 1922, doubled in the course of the 1920s and then continued to grow at 5 per cent a year*." Because oil had to be imported, the changeover to oil in Europe happened much later.

Natural gas was a major by-product of oil and its use quickly became widespread after suitable pipelines were developed and installed in America in the 1930s. Europe – which still used town gas – followed suit in the 1970's, when town gas in Britain was replaced with natural gas from the North Sea. Much of Europe's supply came from Soviet Union gas fields in Siberia. Overall, natural gas progressed from providing 1% of the world's energy in 1900 to 20% in the 1980s.

Apart from coal, oil and gas, only nuclear and hydroelectric power provided any realistic alternatives. In 1929, hydroelectric power was providing 40% of the world's electricity but this declined to 2% by 1990, by which time nuclear power provided a mere one per cent.

During the 20th century, the pattern of the world's energy consumption changed completely. Up until 1900, all energy had been provided by humans, animals, wind and water. *"Now, just over 90% comes from fossil fuels (40% from oil, 33% from coal, and 18 per cent from natural gas … 4% from wood, 2% from hydroelectric and 1% from nuclear) . … During the last two centuries, as in the past, energy supplies have been used as though they are inexhaustible. The industrialised world has encouraged consumption not conservation."*

Because energy was cheap, much of it was wasted; 90 per cent of heat from coal fires went straight up the chimney. The earliest engines were only 2% efficient but, by 1910, steam turbines were achieving 20 per cent efficiency, which almost doubled by the 1950s. Throughout the 20th century, as the natural pressure in oilfields dropped off, wells were repressurised by the injection of natural gas which was then burnt off rather than being recycled: "*In 1913 … one Oklahoma oilfield was wasting natural gas worth more than the oil it was producing."* In the 1920s and 1930s estimates indicate that, in the US, natural gas was wasted at the annual coal equivalent of 25 million tons – amounting to 25% of the world consumption at that time.

The convenience of electricity came at the price of waste, as only 25% of the input energy ended up in the home. Inefficient lamp bulbs, refrigerators and other equipment in poorly insulated homes all add to the waste[9]. *"If individual items of energy producing and using equipment are not always efficient, is modern industrialised society efficient as a whole?"* Crude calculations show that one can offset animal feed against time and effort savings in agricultural tasks. *"But even when the facts are known societies have found it very difficult to make the necessary adjustments to achieve more efficient use of energy"* For example, the far eastern paddy field system of growing rice reaps a return of 50 times more energy than its input, but the return on modern farming is only two-fold and getting worse! *"Overall the energy efficiency of American corn production has fallen by half since 1915 … meat production in the industrialised world now consumes between two and three times the energy it produces … catching and producing fish consumes … 20 times the energy it makes available… and the processing and distribution of food takes three times as much energy as producing the food itself."* In conclusion: *"… all food production in the western world uses three times more energy than it creates."*

Endnotes

1. Some statistics used here are updates of those given by Ponting in 1990; it is sobering to realise that, since the book was published, the world's population has increased by over 1.5 billion. The 2006 figures in this paragraph have been taken from the United States Census International Programs Center.
2. A recent book by John Bligh, 'The Fatal Inheritance' (ISBN1-844-1-336-7) provides excellent further reading on this point concerning the changes that have made it possible to feed so many people.
3. The effects of colonial expansion are covered in detail in Chapter ten of the book/synopsis.
4. When travelling in East Anglia earlier this year during a four week period of no rain, I experienced a vast dust storm rising off the fields as the wind blew the topsoil away just after the seeds had been sown.. Locals told me later this is a common occurrence and farmers often have to re-seed after such an event.
5. Since the UK population was around 42 million in 1910, this amounted to six percent (or one seventeenth) of the population being in domestic service. When children are excluded from the figure of 42 million, then the percentage of the working population would have been much higher – perhaps as much as 10 percent of the working population.
6. Slavery has been dealt with in chapters 7 and 10.
7. During this period, 1830-1900, when the horses kept in towns increased by a factor of 3.4, the population of the UK rose from 16 to 38 million, a factor of 2.4.
8. As fossil fuels are becoming scarcer, the '21st century horse' is already using biodiesel and ethanol from corn, once again setting the use of land for food production in competition with energy production.
9. Things have improved significantly since 1990 and for the greater part energy efficiency is rising, but only because present and anticipated scarcity of fossil fuels has driven up energy prices.

POPULATION PERSPECTIVES USING ECO-FOOTPRINTING

by David Nicholson-Lord

A few months ago the UK magazine *Ethical Consumer* raised with its readers the rights and wrongs of the ultimate consumer "choice". Was it ethical, the magazine asked, to have children? Despite the article's mildness of tone, at least two of its readers decided this was a debate too far, writing in to announce they were cancelling their subscription because of the "extreme", "fanatical", "offensive", "ridiculous" and "totally biased" views expressed.

At roughly the same time the Gaia scientist James Lovelock was predicting that no more than half a billion of us will survive the coming century, as climate change and related disasters take their toll. And Lovelock is by no means alone. Writing in the *The Long Emergency*, published in 2005, author James Howard Kunstler declared that "as oil ceases to be cheap and world reserves move towards depletion, we will suddenly be left with an enormous surplus population that the ecology of Planet Earth will not support."

Taken together, these examples convey an important truth. Given the trade-off between human numbers and the earth's capacity to support them, population is arguably the environmental issue we should all be talking about. Unfortunately, it is also the environmental issue no one wants to talk about.

There are two main reasons for this. The first is its sensitivity: politicians and NGOs view it as potentially alienating of voters, members and funders, and therefore steer well clear. The second is, for want of a better word, its slipperiness. Human population growth is clearly a key cause of the environmental crisis facing the planet but it is not the only cause. How we live — our wants, needs, lifestyles, technologies — is also crucial.

The best-known formulation of this is the IPAT equation popularised by Paul Ehrlich and to be found, in modified form, in the technical sections of successive *Living Planet* reports. This states that human impact (I) is a function of population numbers (P) multiplied by their affluence (A) — sometimes rendered as consumption (C) — and their technologies (T). In other words, there is a synergistic quality to the causes of environmental crisis — and synergies are notoriously difficult to disentangle.

This synergistic quality has made it easier to forget about population since the 1970s and focus on the apparently more amenable aspects of impact-minimisation — renewable technologies, for example. Yet as the American Association for the Advancement of Science's *Atlas of population and environment* (2000) expresses it, "in every human interaction with the environment…the three major elements [population, affluence/ consumption, technology] are in play."

The view put forward by the AAAS is that all "single-issue" explanations of rising human environmental impact "are correct some of the time. None of them is correct all of the time." The implication is that the "main" cause of environmental impact varies through history — sometimes population growth dominates, sometimes affluence or technology. In this light, and given that we are living through the biggest growth in human population in history — from 2.5 billion in 1950 to over nine billion in 2050 — its disappearance from the radar of environmental organisations might seem even less explicable.

Footprinters' main approach so far has been to highlight the overall planetary impact — overshoot, in effect, has been measured in "planets". More recently, an alternative currency of overshoot has become popular — time. Hence the nomination of a day in the year — World Overshoot Day — when we begin to outstrip planetary biocapacity.

The prognostications of Lovelock, Kunstler *et al* in effect treat population as a further measure of overshoot but are inexact. By contrast, Andrew Ferguson and the Optimum Population Trust have actually fed the PAT factors through successive *Living Planet* matrices and come up with some quite precise figures.

What these demonstrate, unsurprisingly, is that the planet can sustain more people living modestly and fewer people living immodestly but either way it is creaking under the weight of current and forecast numbers. Take the UK, for example. OPT's calculations show that, based on *Living Planet* data from 2000 to 2006 (four reports) the UK's sustainable population — the number of people that the UK can support from its own biocapacity — has varied little: 17 million in 2000, 18.2m (2002), 16.7 m (2004), 17.2m (2006). If the UK cuts its energy use by 60 per cent, broadly in line with CO_2 reduction targets, the "sustainable" population figure rises; moreover the estimates based on LPR data remain roughly constant from year to year — 27m (2000 and 2002), 25m (2004), 26m (2006). The UK's actual population is over 60 million. Even if Britons significantly lightened their footprint, in other words, our overshoot would be around 34m people — some 130 per cent.

For the planet as a whole — population currently 6.6 billion — the sustainable figure based on LPR data, matching current footprints and biocapacity while allowing only 12 per cent for biodiversity, has ranged as follows: 3.9billion (2000), 4.4bn (2002), and 4.5bn (2004 and 2006). However, much of the world's population currently lives at or near poverty levels. Factoring in a Western European lifestyle for all the Earth's citizens drastically reduces the supportable global population. Once again the figures, based on LPR data, remain fairly constant from year to year: 2.2bn (2000), 2 bn (2002) and 1.9 bn (2004 and 2006).

But the whole world doesn't have to adopt the present extravagant Western European lifestyle. Suppose it adopted a *modest* Western European lifestyle — using only 40 per cent of current *per capita* Western Europe energy use? What difference would that make to the population the planet could support? The figures tell their own, sombre but consistent, story — 3.1 bn in 2000 and between 2.7 and 2.8 bn for the three *Living Planet* reports since then.

Even based on the latter figures, therefore — which broadly represent a planet with a moderately comfortable but substantially (and possibly unachievably) greener lifestyle — the year 2050 will still see us with over six billion "too many" people, an overshoot of at least 200 per cent. Given figures of such magnitude, weight of footprint must surely be reckoned a far less significant ingredient in the overall "sustainability" equation than the sheer number of feet.

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Lindsey Grant is the author of many books addressing the population problem. I recall that David Willey much admired and often quoted from one of the books that Lindsey edited, *Elephants in the Volkswagen*. Readers of the OPT Journal may also recall that in OPT Journal 5/1, April 2005, I heaped praise upon Lindsey's 74 page book *The Collapsing Bubble: Growth and Fossil Energy*. It was a fine achievement to have captured so much in 74 pages. What follows is an extract from a more recent 52 page booklet, *The Age of Overshoot*, published by Negative Population Growth, Inc. Needless to say the whole booklet is worth reading (and is available for download at the npg website, www.npg.org), but here I have selected just one section (with a couple of introductory paragraphs taken from earlier parts of the booklet). It is particularly appropriate as an outstanding summary of one of the themes that recur in the OPT Journal, namely the lack of realism in the thinking of the great majority of economists, and hence the politicians who follow them.

THE ECONOMISTS' MYTHS

by Lindsey Grant, 782 Coyote Ridge Road, Santa Fe NM 87501, USA

We live between two mutually uncomprehending worlds. Scientists are documenting the rising damage that increasing human activity is causing to the natural systems that support us, but mainstream economists regularly call for more growth and more economic activity. Our present national debate about mass immigration ignores its principal consequence: the dramatic acceleration of U.S. population growth. And at every G8 summit meeting the heads of state proclaim the need for faster economic growth. Either they are in denial of the scientific evidence or they suffer from cognitive dissonance and try to hold two irreconcilable views of reality at the same time. …

I will try to show where the mainstream economists go astray. (I use this term as a convenient shorthand. There are economists who recognize the perils of continuing growth, but the conventional economists ignore them.). …

There are two major impediments to addressing population policy: the faith in growth; and the hope for simple, usually technical solutions. First, the faith in growth.

The capitalist economists should not be blamed too harshly for the tenacity of their mind-set. After all, their formulas worked pretty well for 200 years, at least for those who run the system — but in a less populous and consuming world. They believe they know about economics. They should reciprocate and acknowledge that scientists know more about natural systems than they do. They pretend that efficiency and new technologies will make continuing growth benign, but that belief rests on faith, not proof. They need to learn about sustainability from those who study it. Macroeconomics is not the appropriate discipline for understanding the consequences of growth.

Growth: the Capitalist Mindset. John Maynard Keynes, the archdruid of modern economics, looked forward in a 1930 essay to a day when people will "once more value ends above means and prefer the good to the useful..." But he went on to argue that "The time for all this is not yet. For at least another hundred years we must pretend to ourselves and to every one that fair is foul and foul is fair; for foul is useful and fair is not. Avarice and usury and precaution must be our gods for a little longer still. For only they can lead us out of the tunnel of economic necessity into daylight."[1] In other words, the system is based on greed, but we cannot escape it for the foreseeable future.

Keynes' followers have ignored his moral qualms and latched on to his cynical tactical advice as to how to make the economy grow. There is no theory of limits in post-Keynesian economics. The economy is considered healthy only when it is growing at 3 or

4% a year. That means a doubling of GNP about every two decades. It takes only a few doublings for the scale to reach the absurd, in a finite country on a finite planet, but growth proponents don't look that far ahead.

We see here, baldly, the conflict between an implacable human urge and the calculations of science. To say which approach is rational is not to predict the likely winner. The scientists are wrestling with an 800-pound gorilla: greed.

Theoretically, it is immaterial to the macroeconomists whether growth comes from larger numbers or increased individual consumption. Either way, growth benefits the successful entrepreneurs. To watch big business and investors in the modern United States, one must assume that they prefer the larger population approach, since they are the most intense advocates of mass immigration, which furnishes cheap labor, at the price of massive population growth.

The result is an increasingly frantic and crowded nation. I would submit that we have lost more than we have gained as we have lost the sense of space and silence that the country once enjoyed. Crowding detracts from human well-being, and crowding is a function of sheer numbers, of consumption levels, and of income distribution. The best and most space has always gone to the powerful and the rich, but it was perhaps less important when humans were less crowded and there was more space to go around.

There seems to be no limit to the appetite of the powerful for more money. So far, the working classes have put up with that appetite, in the United States, because of the widespread hope that they, too, can enter the gilded minority. In Europe, and apparently now in Latin America, they are not so forgiving, and that has given rise to populist governments and demands for redistribution. We should take heed. There is a strong moral case against the widening gap between the wage earners and the super-rich.[2] To give a more pragmatic argument: the energy transition will inevitably be a period of retrenchment. If we go into that transition encumbered by class hostility and struggle, we will find it much harder to make the sacrifices necessary for the common good.

GNP as Myth. The growth goal is usually stated in terms of Gross National Product (GNP) or Gross Domestic Product (GDP), both of which ostensibly measure a nation's total output of goods and services. But they measure only those activities that enter the money economy. They put a value on cutting down a forest, but no value on the forest that is destroyed.[3] They inflate growth by measuring the investments in irrigation systems to supplement the rain, but they do not measure the value of the rain. They record with magisterial indifference the creation of pollution and the expenditures on its control. They ignore production for home use, including subsistence farming. If China's GNP accounting follows those rules, its remarkable recent GNP growth is thus in part an artifact. It documents what is happening to the modern sector but not to the resource base, or to the majority of Chinese who are down on the farm, except insofar as they send their young people off to work in factories.

There is no necessary connection between rising GNP and rising wellbeing. Very little money moved in pre-modern agriculture, but it could be quite prosperous if there was enough good land per person. The term "subsistence economy" has a bad name right now, but that is partly a function of the paucity of resources per capita. And the larger the population, the less land per capita.

On the other hand, GNP includes many things that offer no pleasure in themselves but are necessary in complex societies — things such as urban infrastructure costs, parking meters, superhighways, highway police and security systems. Taken together, the things we don't really enjoy but must have in a modern society probably constitute a good portion of the whole — including the cost of governments that intrude in every part of our lives, in order to manage the tensions that come with crowding.

The economists argue that we are getting more efficient, and that GNP growth does not require equivalent growth in energy and resource use. Partly true, but not true enough. In the United States, we have cut our energy use per dollar of GNP as we move from heavy industry to a service economy and let the rising nations have the heavy industry. But that is not a particularly meaningful statement. China and India are growing nearly 10% per year — doubling every 7-10 years, and it is energy-intensive. In the United States, energy use per capita has risen steadily and swiftly for more than a century. Now, facing the energy transition, it is poised to drop, slowly at first and then precipitously through this century.

The argument for fewer people and a smaller economy is driven by that energy calculation, but it also becomes attractive if we recognize that, in the prosperous nations, we don't need a rising GNP except as a way of making more growth tolerable.

The developing countries, on the other hand, need to escape from poverty. They want to do it the way we have, with massive consumption, but most of them missed the free ride of the fossil fuel era, and they may need to content themselves with a more modest definition of well-being, even as a goal.

Infinite Substitutability. This term embodies the conventional economists' would-be answer to limits. Sure, substitutability works, up to a point. We can all think of substitutes that came into use when the original resource declined or became too expensive. Some substitutes (such as plastics for metals) may or may not be as good as the original. Others (such as particle board for heart pine) are a long step down. But the "infinite" is the hooker. Name a substitute for water. Or energy. Or food. Or, at a more sophisticated level, consider the unorthodox economist Herman Daly's point that different inputs are more likely to be complementary than substitutes. When a forest is cut down, you cannot maintain lumber production by adding sawmills.

Free Trade. This is traditionally a tenet of the powerful, not the weak. It justifies their demand for open markets, investment opportunities abroad, and access to resources. If there were no constraints on resources, it could be good for both trading partners, through the doctrine of comparative advantage. But comparative advantage no longer works when the powerful are free to move capital and know-how to the place where production costs are cheapest, and when they can then sell without restraint in any market, using their deep pockets and marketing machinery to drive out local competitors. When that happens, it drives wages everywhere toward the level of the lowest labor cost. This hurts labor and generates social unrest in the richer countries. It does not help the poorer countries when the capitalist suddenly shifts his production to a cheaper country. Witness what has been happening to Mexican labor as U.S. industrialists have closed the Maquiladora factories and moved on to other countries with cheaper labor costs.

The “free trade” slogan is used cynically, and it may not reflect reality. The NAFTA document is hundreds of pages long, most of which are devoted to maximizing U.S. business’ operating freedom in Mexico rather than to free trade itself. The Doha Round of GATT has been stalled as Europe protects its agricultural exports and the United States protects its intellectual property. And it doesn’t work when exports are subsidized (as are U.S. agricultural exports), or when there are serious scarcities. In recent decades, the United States has banned soybean exports to protect domestic consumers in a bad year, and the European Union has done the same for wheat.

Now, OPEC and the principal oil exporters are coming to recognize that they have the whip hand in the petroleum market. In Bolivia, we are running into increased protectionism for its gas resources. Mexico nationalized its oil in 1938, and Saudi Arabia in the 1950s. I wonder what will happen to free trade when we become the Saudi Arabia of coal.

“Free trade” has become the cover for the effort to obtain others’ resources. But we are in idiots’ heaven if we think it will work. Russia has become increasingly assertive about squeezing out foreign oil companies and using its gas and oil resources for political ends. Witness its negotiations with the Ukraine, Georgia, and now Byelorussia. In its talks with the European Union about continuing its gas sales, it has made the EU increasingly nervous about being dependent on such a threatening neighbor for the gas supplies that are essential to run their economies and even to keep warm.

The European Commission, as a consequence, has formulated a dramatic set of policies to promote renewables and reduce its dependence on gas and oil. They are tough policies, and the European electorates may not be willing to swallow the medicine, but Europe at least is far ahead of the United States in its willingness to talk about real and sweeping changes to meet the problem, rather than offering palliatives.

“Free trade” may for a time purchase cheap goods at the expense of devalued workers here and abroad, and at the cost of destroying our manufacturing base. It is not a justification for growth beyond our means, since it offers no real access to resources beyond our own control. A century and more ago, because of the costs of transportation, countries (or regions) tended to be self-sufficient in the essentials such as food and energy. In terms of basic security, if not of growth, there is much to be said for that condition.

“Economic Man” is the myth used to justify brutal labor policies in the pursuit of growth and more profits. Modern economics is betting on the wrong horse. It promotes efficiency — which means fewer jobs to do the same work — at the same time that it imports cheap labor, drives wages down and exports jobs. To justify these policies, it posits “economic man”, who moves easily and swiftly into another, better job when the one he had disappears.

The real world doesn’t work that way. Various recent studies of displaced workers have found that more than half eventually find new jobs, but most of them must accept lower wages and fewer benefits.

The loss of income forces a reduction in living standards. There is a widening inequality between wages and the income of the rich, and between workers’ productivity and their wages. In the United States, supposedly the model of successful capitalism, hourly wages have stagnated for three decades. To see the impact of free trade on wages and benefits, look at the agonies the U.S. automobile industry is presently going through as its wages, medical benefits and retirement plans are under assault from foreign and non-union domestic competition.

Japan apparently is entering the same condition of soaring profits and stagnant wages.[4]

Even that is perhaps less important than the loss of a job. Humans tend to find their identity in their work. Joblessness leads to hopelessness, frustration and anger. Our official unemployment statistics conceal the real level of joblessness. They show about 5% of the labor force as unemployed, but about 33% of the civilian "non-institutional population" (i.e. not in prison or school) 16 and over is not in the labor force. (They don't even show up as "unemployed.") For young minority members, the proportion can run over 50%. Some of those people don't want to work. Many do, but they have dropped out of the hiring halls and other measures of "seeking work." This is the real measure of wasted people.

Modern economics, in short, promotes policies that benefit the entrepreneur but not the laborer. It does not serve the working class, but it wins acquiescence by offering the evanescent benefit of cheap goods.

The economists' own law of supply and demand suggests that a smaller work force, relative to the economy, would earn better wages, but that does not happen if free trade serves to drive wages downward. A diminishing population would profit from that law, but it is hardly the mainstream economists' choice.

Our pattern of mass immigration drives down the price of U.S. labor, but unlike free trade, it also perpetuates the problem into the future. Because most of the immigrants we choose to allow in (legally or otherwise) are from the more fertile components of traditionally fertile societies, immigration policy is accelerating U.S. population growth.

Taken together, the capitalist economists' myths may reassure them and their followers that they are not immoral, but they are internally inconsistent and they do nothing to address the problems of limits I have described.

If I seem to have spent an inordinate amount of time beating up on the macroeconomists, it is because they are the most persistent and effective advocates of growth and of the immigration that drives it, and we must learn to rebut their vision if we are to escape the fate toward which they would lead us.

Endnotes

1. From E.F. Schumacher, *Small is Beautiful. Economics as if People Mattered* (New York: Harper & Row, 1973), p. 24. This paragraph was quoted in *Juggernaut*, op cit.
2. The *New York Times* (4-9-06) and even the *Wall Street Journal* (1-19-06), that bastion of capitalism, have recently carried articles critical of the widening income spread.
3. Be it said that a few economists, with the United Nations' blessing, are trying to develop a measure that includes the increase or decrease in national resources.
4. Yuka Hayashi, "Japan's Profits Rise, but Wages Stagnate", *Wall Street Journal, 1-16-07, p. A2.*

THE POWER DENSITY OF ETHANOL FROM BRAZILIAN SUGARCANE

by Andrew R.B. Ferguson

Abstract. The power density of ethanol produced from sugarcane in Brazil is about 2.9 kW/ha. That is equivalent to capturing a little more than a thousandth part of solar radiation, and is also a little more than a thousandth part of the power density we are used to from oil and gas. So ineffective is 2.9 kW/ha, that about 5 million ha of land would have to be put down to sugarcane *every year* just to satisfy the increase in transportation energy demand that results from the annual expansion of population in the U.S.A.

In an eleven page paper, *Sugarcane and Energy* , the relationship between sugarcane and energy has been covered in considerable detail (Ferguson, 1999); however it may be useful to make available a more concise summary of this essential question: what is the power density of ethanol from sugarcane? The question needs to be asked since one great problem with biofuels is their low power density.

The lack of agricultural potential in the USA to achieve anything significant from biofuels has been superbly demonstrated by Donald F. Anthrop, professor emeritus of environmental studies at San Jose State University, in the *Oil and Gas Journal*, Feb.5, 2007. For instance, he brought up the fact that if the whole of the US corn crop were to be devoted to producing ethanol from corn, this would satisfy only 11.5% of gasoline demand in the US. Note, too, that the reference is to gasoline, and since gasoline represents about half of transportation fuels, it could also be said that the ethanol produced would satisfy only about 6% of transport fuel. My thanks go to Walter Youngquist for sending me this important paper.

Donald Anthrop did not cover sugarcane, and since the 'energy fantasists' are not easily brought to see reality, some will doubtless hold on to the hope that the supposedly huge unused acres of Brazil can come to the rescue. Thus a look at the power density of ethanol from sugarcane would appear to be timely.

As with all liquid biofuels, there are various power densities which could be assessed:

a) The calorific value of the ethanol produced each year per hectare of land.

b) The calorific value of the 'useful' ethanol produced each year per hectare of land, that is *after* subtracting the portion of ethanol that is needed for input into the agricultural and production processes.

c) The calorific value of the ethanol and by-products produced each year after subtracting the calorific value of *all* the inputs. This is the *net* energy capture (or *net* power density).

Choice (c) might seem to be the most revealing analysis, but there are both practical and almost philosophical questions about how to assess the inputs, particularly: (1) to what extent it is misleading to subtract the calorific value of non-liquid inputs from the calorific value of liquid outputs; and (2) what value should be assigned to by-products, especially when some of the by-products could be used to improve soil fertility and prevent erosion.

Table 1. Average energy inputs and output per hectare for sugarcane in Brazil.

	Quantity/ha	10^3 kcal/ha
Inputs		
Labor	210 hr	157[a]
Machinery	72 kg	1,944
Fuel	262 liters	2,635
Nitrogen (ammonia)	65 kg	1,364
Phosphorus (triple)	52 kg	336
Potassium (muriate)	100 kg	250
Lime	616 kg	192
Seed	215 kg	271
Insecticide	0.5 kg	50
Herbicide	3 kg	300
Total		**7,499**
Output		
Sugarcane (fresh)	71,400 kg[b]	

Table 2. Inputs to transform 71,400 kg of Brazilian sugarcane (fresh) to ethanol

	Quantity/ha	10^3 kcal/ha	
Inputs			
Sugarcane (fresh) as per Table 1	71,400 kg	7,499	
Transport	71,400 kg	994	
Water	482,140 kg	270	
Stainless steel[c]	12 kg	174	
Concrete[c]	31 kg	58	
Bagasse (fresh) [d]	21,340 kg	38,760	
Pollution	–	–	
Total		**47,755**	
Gross output of ethanol = 5,525 liters =		28,343	
Liquid inputs = 47,755 x 0.14 =		<u>6,686</u>	
So output of ‘useful’ ethanol		21,657	= 4,222 liters ethanol/ha/yr.

So power density = 21,657,000 kcal/ha/yr = 90.7 GJ/ha = **2.9 kW/ha**

Notes to Tables

a. There is some debate as to whether the energy associated with the labor input should reflect the lifestyle of the laborers, but that is not germane to this analysis.

b. The original tables were associated with 54,000 kg of sugarcane. No increase in inputs have been introduced into Table 1, and the only items that have been proportionately increased in Table 2, to allow for the 71,400 kg of sugarcane, are transport and the heat provided by the bagasse.

c. The embodied energy associated with these raw materials are amortized over their lifetime.

d. The calorific value of fresh bagasse is 1816 kcal/kg (see Ferguson, 1999), which is used to calculate the weight. Bagasse is a by-product and is used to produce the heat needed for the transformation process, thus arguably its energy content need not be included in an input/output analysis. It is relevant here anyway because it helps in the assessment of the required liquid inputs.

Albeit at the cost of being potentially misleading, the type (b) analysis gets around that, and so is a useful starting point, but it requires an assessment of the liquid inputs needed, for which data are not always available.

Although using corn (maize) as feedstock to produce ethanol differs in several important respects from using sugarcane, there is bound to be a degree of similarity in the amount of *liquid* inputs needed as a fraction of the *total* inputs. So as a guide, let us look at a statement in Shapouri et al, 2002:

> As discussed earlier, some researchers prefer addressing the energy security issue by looking at the net energy gain of ethanol from a liquid fuels standpoint. In this case, only the liquid fossil fuels used to grow corn and produce ethanol are considered in the analysis. On a weighted average basis, about 83% of the total energy requirements come from non-liquid fuels, such as coal and natural gas.

That is clearly a statement of method (b) above, and it implies that 17% of the inputs need to be in liquid form. However, we should not take corn as being too accurately aligned with sugarcane in this respect, so I build in a 3% error margin, and assume that only 14% of the total inputs needs to be in liquid form.

To establish the power density of sugarcane I have, with the kind permission of David Pimentel, reworked the tables on pages 238-239 of *Food, Energy, and Society* (Pimentel and Pimentel, 1996), which refer to sugarcane production in Brazil, updating the yield to the latest average yield which is being achieved over 5.2 million hectares of sugarcane. From Table 2 we have the answer to our question. It is that the power density achieved in producing ethanol from sugarcane in Brazil is about 2.9 kW/ha — but that is on the very lenient measure of accounting only for the liquid inputs.

One thing to note is that sugarcane is usually grown in sunny areas, so the insolation would be around 2200 kW/ha, so the energy capture is only a little more than 0.1% of insolation, that is a bit more than 1 part in a thousand. This is very relevant in the context of the fact that 'energy fantasists' like to dwell at length on the amount of solar power that is available, as though we are likely to capture much of it.

It is not easy to conceive of the paucity of 2.9 kW/ha. Another useful way to look at the matter is to consider that while it is hard to measure the power density of oil and gas, it is clear that the figures are numerically in the region of solar insolation in the United States, that is about 2000 kW/ha. So capture of sunlight in the form of ethanol achieves a power density that is once again only a bit more than a thousandth part of what we are used to enjoying while oil and gas are available.

A further point of reference is to consider how much land would be needed to provide the burgeoning U.S. population with liquid fuel using ethanol from sugarcane. Dividing transportation fuels by the number of citizens, each American uses, on average, about 3 kW of fuel for transportation (out of a total energy use of about 10.5 kW). Virginia Abernethy (2006) has pointed out that the Census Bureau greatly undercounts the extent of illegal immigration, and that the correct figure for the growth of the U.S. population is between 4.7 and 5.7 million per year. Taking a central figure of 5.2 million, since each American would need 3 / 2.9 = 1.03 ha to provide transport fuel from ethanol, there would be a need for an additional 1.03 x 5.2 million, say 5 million hectares to be put down to sugarcane *every year*, just so as to keep pace with the expansion in population. It is clear that even borrowing land freely from Brazil this becomes impossible within a decade.

There is also this moral question: will conscience allow us to satisfy the motoring public this way when the WHO assesses that 3700 million are suffering from malnutrition and over 800 million from hunger? Not everyone will be as unconcerned about that as President George Bush, who in his State of the Union address called for a 20% cut in gasoline consumption by 2017 and indicated that biofuels would provide a substantial part of the solution. Yet surely his advisers told him that the power density of ethanol from corn, assessed on the same basis as above, is lower than for sugarcane, being about 2776 liters of ethanol/ha/yr = 59.0 GJ/yr = 1.9 kW/ha (see OPTJ 3/1, p. 12 for more detail), and other biofuels have even lower power densities (excepting sugarcane). Biofuels can hardly be regarded as even part of the answer when, as we have seen, the growth of biofuels could not match the growth in U.S. population. Insofar as that attempt is made, it will continue to increase the cost of food. Donald Anthrop showed that to be happening, with figures that illustrated a 94% increase in the contract price for corn, between March 2006 and March 2007.

Errors and the potential for more relating to sugarcane

The subject of sugarcane seems to abound in substantial errors, and perhaps the ‘energy fantasists’ cling on to them. It may be the very high moisture content of sugarcane (about 70%) which causes confusion. Anyway information sources which are otherwise reliable contain gross errors both about ethanol from sugarcane and sugarcane itself.

The most egregious must surely be that in an old book *Biological Energy Resources*, 1979, by Malcolm Slesser and Chris Lewis. Several times it is repeated therein that the yield of ethanol from sugarcane is about 17 tonnes per hectare per year. That would be 457,300 MJ = 21,520 liters of ethanol. Because Brazil is the place where the ‘energy fantasists’ assume there are boundless hectares of potential sugarcane land, we have taken Brazil as an example, but even with a high yield of 88 tonnes of sugarcane per hectare, as might be obtained in Louisiana, the ethanol yield would only be about 6290 liters.

Regarding sugarcane itself, Howard Hayden, in the revised edition of his book *The Solar Fraud*, page 242, states that the power density of “Sugar cane (whole plant, tropical conditions, plenty of fertilizer and pesticides)” is 37 kW/ha. That is far too high. Once again taking the high yield of 88,000 kg of fresh sugarcane, the calorific value would be about 88,000 x 1212 kcal/kg = 107 million kcal/ha/yr = 446 GJ/ha/yr = 14 kW/ha. The figure is easy to cross-check, as 88,000 kg at 70% moisture content would contain 26,400 kg of dry matter, and as dry matter has an energy content in the region of 4180 kcal/kg, the calorific value must be in the region of 110 million kcal.

A hope which lingers around (so far only a potential error) is that the by-product bagasse is so plentiful that it can not only provide the heat needed to carry out the distillation processes but also contribute large amounts (‘energy fantasists’ steer clear of giving actual figures!) of heat for providing electricity. That too has now been quantified, and amounts to only 0.1 kW(e)/ha. Clearly that is hardly significant, and anyhow it is doubtful that the bagasse should be put to that purpose, as the next section makes clear.

Soil erosion problems

It will be noted from Table 2 that the heat value of the bagasse used to effect the transformation of the sugarcane to ethanol amounts to about 1.8 times the amount of useful ethanol produced. So it is true to say that the only reason that producing ethanol from sugarcane is not a very substantial energy loser is that the heat can be provided by the bagasse instead of from fossil fuels. However it is doubtful that much of the bagasse should be so used if the sugarcane production is to be truly sustainable, for one dire problem with sugarcane is its tendency to cause soil erosion (Pimentel, 1993). That is a matter of considerable importance to which we will now turn.

Corn has a total yield of around 15 dry tonnes, half being grain and half stover (Pimentel and Pimentel, 1996, p. 36). With reference to corn, David Pimentel has continually stressed the problems arising from soil erosion, and the need to keep all the stover on the ground to maintain the fertility of the soil. Thus in the case of corn about the maximum biomass that should be removed permanently is 7.5 dry t/ha/yr. The Brazilian sugarcane we are considering has an average yield of 71.4 t/ha/yr fresh which is 21 t/ha/yr dry. To remove no more dry matter than recommended for corn, 14 dry t/ha/yr (47 tonnes fresh) of sugarcane biomass should be either left on the soil or returned to it. Also common sense dictates that it is not sustainable to remove 21 dry tonnes of biomass from the land each year without sooner or later causing soil impoverishment and erosion.

We can conclude that while it is possible to deliver a 'useful' 2.9 kW/ha as liquid fuel from Brazilian sugarcane, there would need to be considerable 'external' inputs to replace the heat provided by the bagasse if the process is to be made sustainable by maintaining soil quality and preventing soil erosion. While that is not relevant to the uncontentious power density calculations of this paper, it does remind us that the simplified calculation of power density made here — so as to escape the more philosophical points of *net* energy — does not paint the full dismal picture of the great difficulty of producing liquid fuels sustainably.

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Thanks to a cutting that Walter Youngquist sent me, I can introduce Alan Ferguson (no relation as far as I know) who sees some aspects of the world realistically. One must regret his implied doubts about global warming, and certainly his failure to recognize the paramount importance of population; however he has it exactly right with respect to interaction between democratic governments and their electorates, and regarding the absence of renewable energy solutions. Below are some extracts from his Opinion piece, dated 17 May 2007, which was published in *The Province*, a daily newspaper in Vancouver, British Columbia.

So does the OPT still have a role if everything that Alan Ferguson says is true? Certainly! China has shown that it is possible to introduce draconian population policies, and Iran has shown that it can be nearly as effective to do it by persuasion rather than compulsion. But can it be done in democracies? Western Europe already has a total fertility rate of 1.6, which would mean a declining population without net inwards migration. One thing that democratic governments could do, without "electoral oblivion," is to *praise and encourage* small families, and turn off the tap of net inward migration.

POLITICAL REALITIES IN DEMOCRACIES

Extracts from an opinion piece by Alan Ferguson

Public hysteria over global warming has reached such absurd heights that governments are forced to act or risk dismissal.

But if they did what was truly required to counter the perceived threat, the sacrifices demanded would just as surely consign them to electoral oblivion.

Luckily for them, they know that, for all the nervous twittering over climate change, most people are unwilling to make any personal sacrifice at all — as a poll this week convincingly confirmed. So what governments do is cobble together illusory green agendas in an effort to calm the hysteria, while keeping the economy afloat. Take the new love affair with ethanol, for example. In both Canada and the U.S. this fuel, made from corn, is being touted as a "clean" alternative to fossil fuels. Vast acreages are being planted, not for food needed to fight famine, but to fuel SUVs.

As *Foreign Affairs* magazine noted: "Filling the 25-gallon tank of an SUV with pure ethanol requires over 450 lbs of corn,[1] which contains enough calories to feed one person for a year. …

Palm oil is actually a more efficient biofuel than corn. Thus, in Indonesia and elsewhere, ancient forests are being levelled to grow palms.

The impact on the environment is as devastating as any of Gore's dire predictions. The cruel irony is that the havoc is being wrought in pursuit of the goals he espouses.

The really inconvenient truth is that human existence is endangered through our unbridled appetite for material "progress," of which man made climate change is only one supposed symptom.

1. Editor's note: Alan Ferguson assured me that *Foreign Affairs* printed the figure of 450 lbs of corn. But it is not quite right. 25 U.S. gallons = 94.6 litres and each litre of ethanol requires 2.6 kg of corn, hence the requirement is 246 kg = <u>540</u> lbs, rather than <u>450</u> lbs. A further point is significant, although it is not relevant to the business of filling a 25-gallon tank. It is that the energy density of ethanol is about 21 megajoules/litre compared to about 33 MJ/litre for gasoline, so 25 gallons of ethanol is equivalent, in its ability to propel a vehicle, to about 16 gallons of gasoline. That lower energy density, of course, relates only to the need to fill the 25-gallon tank more often.

DEMOGRAPHIC SIGNIFICANCE OF THE 40 FACTOR

by William Stanton. Kites Croft, Westbury-sub-Mendip, Wells, Somerset. BA5 1HU

Human survival depends on there being enough food and drink to support life. Fresh water is easily obtained in many parts of the world. Food, on the other hand, has to be grown, raised or hunted. Producing enough of it, by agriculture, is serious work. Before about 1750, when the Industrial Revolution began, farmers depended on human and animal muscle. Now, in all but backward societies, diesel-powered tractors and mains electricity have taken over. The increase in efficiency, thanks to fossil fuels, is colossal.

Over the hedge from my garden is a hay meadow 7 acres (2.8 hectares) in area. Mowing it by tractor takes about 1.5 hours. This compares to the full day, including breaks for food and cider, that a man with a scythe traditionally took to cut one acre. The tractor is roughly 40 times more efficient in terms of man-hours.

The next two procedures in modern haymaking, tedding the cut grass to dry it, and then baling it, each take the tractor about 1.5 hours. Before 1750 the farm workers, men and women, used rakes to aerate and dry the hay, then loaded it into carts with pitchforks. Again the efficiency ratio is something like 40:1.

A giant combine harvester with its satellite tractors and trailers may be 100 times as effective as the peasants with their sickles and threshing floors in recovering the grain from large acreages of cereals.

Medieval woodcutters harvested energy with sharp axes. Several of them would have taken a day to load their cart with logs and haul it from the forest to the village. Thanks to my chain saw I can fill my car with logs cut to size and bring them home, a mile from the wood, in two hours.

Only 60 years ago, before piped water reached the streamless limestone plateau of the Mendip Hills, my neighbour’s cattle were supplied in summer by a horse and cart that carried a few large churns of water up the hill from the farm to a tank on the plateau 150 metres higher. The horse and driver managed 2 journeys a day to water the little herd of about 10 animals. Now there is no limit to the number of cattle that can be watered.

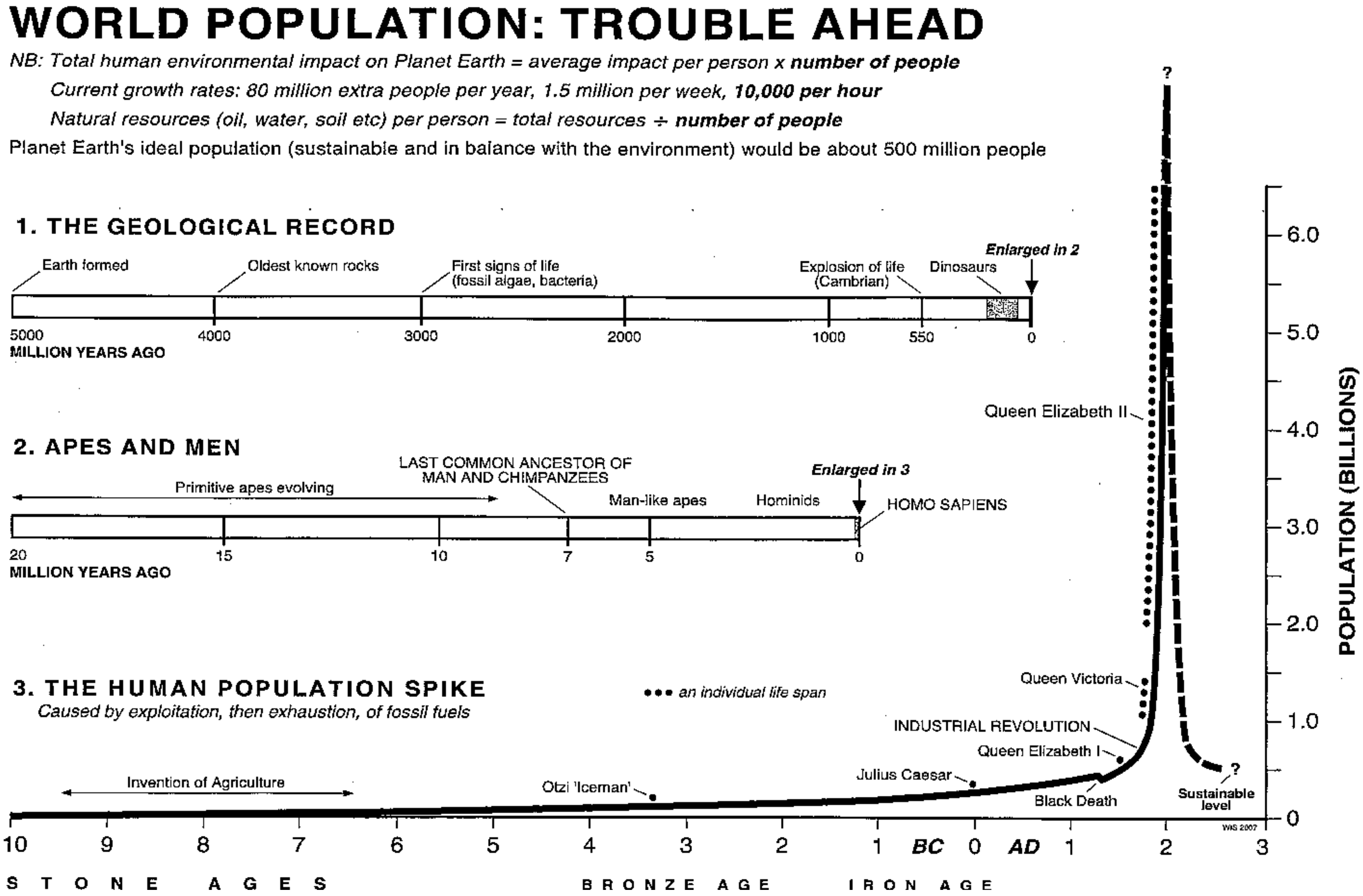
Picture the dairymaid on her three-legged stool, milking about 5 cows every hour by hand a century ago. Now, only the capacity of the milking parlour limits the size of the herd, sometimes as many as 400, that can be processed in two or three hours.

Whether it be ploughing the fields, hedging and ditching, clearing out ponds, or raising livestock, few modern agricultural procedures are less than 40 times as efficient, in terms of time taken to produce food, as they were when the work was done by humans, with or without farm animals. The same applies to working the oceans, where huge factory ships, trawlers and bulk carriers have replaced wind-powered fishing boats and tea clippers.

The significance of this “40 Factor” cannot be exaggerated. How long do we have before fossil fuels are so scarce that global food production begins its shrinkage to a very small fraction of what we can currently produce?

According to the prestigious Association for the Study of Peak Oil and Gas (ASPO), annual production of conventional oil peaked in 2005 at 24 Gb (billion barrels) and total oils (including heavy oil, tar sands, oil shales, deepwater oil, polar oil, and gas condensates) are expected to peak in 2011 at 33 Gb. All hydrocarbons including gas will peak about 2012. The world’s large coal reserves are fairly irrelevant because they are slow and expensive to mine and process into liquid fuels.

So the downhill slide in fossil fuel production, food availability and world population may well begin around 2012. Depending on a host of variables it could end around 2150. The journey will be eventful, to say the least, and we must hope that our descendants will have learned from it as they try to survive in the hard world of non-fossil energy.


WORLD POPULATION: TROUBLE AHEAD
NB: Total human environmental impact on Planet Earth = average impact per person x number of people
Current growth rates: 80 million extra people per year, 1.5 million per week, 10,000 per hour
Natural resources (oil, water, soil etc) per person = total resources ÷ number of people
Planet Earth's ideal population (sustainable and in balance with the environment) would be about 500 million people
1. THE GEOLOGICAL RECORD
Earth formed
Oldest known rocks
First signs of life (fossil algae, bacteria)
Explosion of life (Cambrian)
Dinosaurs
Enlarged in 2
5000
4000
3000
2000
1000
550
0
MILLION YEARS AGO
2. APES AND MEN
Primitive apes evolving
LAST COMMON ANCESTOR OF MAN AND CHIMPANZEES
Man-like apes
Hominids
Enlarged in 3
HOMO SAPIENS
20
15
10
7
5
0
MILLION YEARS AGO
3. THE HUMAN POPULATION SPIKE
Caused by exploitation, then exhaustion, of fossil fuels
••• an individual life span
Invention of Agriculture
Otzi 'Iceman'
Julius Caesar
Black Death
Queen Elizabeth I
INDUSTRIAL REVOLUTION
Queen Victoria
Queen Elizabeth II
?
?
Sustainable level
WJS 2007
10
9
8
7
6
5
4
3
2
1
BC
0
AD
1
2
3
STONE AGES
BRONZE AGE
IRON AGE
6.0
5.0
4.0
3.0
2.0
1.0
0
POPULATION (BILLIONS)

THE LIMITS TO WIND PENETRATION IN THE UK

Andrew R.B. Ferguson

Abstract. A recent study in the UK removes the largest remaining uncertainty surrounding the limits to wind power in the UK. The study shows that weather systems cover a larger area than the UK, so that building taller wind turbines and spreading them from the Shetlands to Cornwall does not change the all-important ratio between the peak infeed factor — the maximum delivery from the wind that occurs under favourable wind conditions — and the capacity factor, or load factor, which of course is the mean infeed over the year. This suggests that an upper limit of 20% of the electrical supply can be set as the maximum contribution of wind, but whether it will be possible to manage such a large uncontrollable input is still in doubt. 20% of electricity would replace about 7% of total energy demand. The UK provides a general guide to the limits of wind penetration.

The recent study, dated 7 December 2006, by Oswald Consultancy Ltd for the Renewable Energy Foundation is exceptionally important, because it answers the vital question as to what would happen if the UK were to have an enhanced and widely distributed wind system. The title of the report is **25 GW of Distributed Wind on the UK Electricity System**. The full twenty-one page report is available in pdf format. It is only just over a megabyte in size, and can be printed out or saved to disk without restriction. It can be found at: http://www.ref.org.uk/images/pdfs/ref.wind.smoothing.08.12.06.pdf

One of the weather maps in the report shows at a glance why we should expect the results that the report arrives at: the fact is that weather systems are often larger than the UK, so what happens in Shetland is fairly likely to be happening in Cornwall. What is even more convincing is to see precisely the results that would obtain through twelve Januarys, 1995-2006, based on actual weather reports, which are translated into wind outputs from turbines located at the windiest places and spread over the length and breadth of the UK; and then to see what the result will be when those outputs are integrated.

Thus the report fills in the most important gaps in our present knowledge about introducing electricity from wind turbines into the UK. It leaves little doubt about the *theoretical* upper limit to the wind penetration that can be achieved without using storage, namely about 20%. The report studies 25 GW of wind capacity, and by making scale adjustments for larger wind turbines it arrives at a mean capacity factor of about 35%. At that capacity factor 25 GW of wind would deliver 19% of UK electricity. Whether operation of an electrical system with so much uncontrollable input is practical needs further discussion, and will be covered later.

It must be borne in mind that a solution to the problem of storing electrical energy would change the picture, but large scale storage is an unsolved problem.

The great hope of wind enthusiasts has always been that by spreading wind turbines over the whole UK, it would be possible to overcome the major problem of wind turbines, which is the difference between their capacity factor (also called load factor) and their peak infeed factor, which is the peak infeed that ever comes from all the turbines together. The Oswald study chose eight sites stretching from Shetland to Cornwall, including Caithness, Southern Scotland, Cumbria, West Yorkshire, Wales, and Norfolk. The points chosen were where there were Met office stations with wind farms nearby to check the accuracy of the model. The Met offices were necessary because the study was not based just on present capacity factors, but calculated to cover twelve years, and with an increase in capacity factor arising from increase in turbine height. This resulted in raising capacity factors by 26% above those currently being achieved; thus with the example given, the 28.2% capacity factor achieved in 2005 was raised to 35.5%. 2005 is a fairly typical wind year, so it can be said that this study is essentially of a widely spread wind system with a sufficiently high turbine hub height that the average capacity factor is raised from its current level of close to 30% to about 35%.

But peak infeed factor is as important as capacity factor. The Oswald report lists the maximum power change and the minimum power achieved by the complete system in the month of January, for the 12 years 1995 to 2006 inclusive. This implies the peak infeed factor. There was an exceptional year in 1999, when the peak infeed factor reached 99.6% of full rated power. But on average over the 12 years, during the month of January, the peak infeed factor was about 98%.

Although the report does not make the point in precisely this way, combined with the capacity factor of 35%, a back-of-the-envelope calculation shows why this means that wind can supply only about 20% of electricity. If wind can contribute 35 / 98 = 36% towards a 'block' of electricity, then the remaining 64% must be supplied by controllable sources operating 'in harness'. But that does not mean that wind could satisfy 36% of all electricity. Since low demand is about 60% of mean demand, that implies that wind can satisfy around 0.60 x 36 = 22% of total demand. As mentioned above, that is not how the report puts it. Rather it demonstrates that 25 GW of wind capacity, while providing 19% of electricity demand, would stretch the grid system to the limits, as we shall see.

We should also take note of the fact that the 19% figure assumes that there is no nuclear power in the system that has to be allowed to operate a steady baseload, for that would use up some of the 'block' that otherwise wind, in harness with controllables, could serve.

One chart in the Oswald report shows the background variability of demand that arose each day during the month of January, using 2005 as an example. The variation in power demand through each day was about 20 GW (1 gigawatt = 1000 MW), therefore that amount of fully flexible capacity is needed even on a system with no uncontrollable infeeds coming from such sources as wind.

The addition of 25 GW of wind capacity is seen in the next chart in the report. That chart shows the residual demand which controllable sources would have to supply once 25 GW of wind has been introduced into the system. There are still about 30 peaks during the month but the excursions are wider and more erratic, varying from 10 GW on some days to 35 GW on other days. Moreover during the course of the month January 2005, the variation in residual demand (i.e. to be filled by controllables) is shown as 50 GW.

More precisely, through the course of that month the residual demand varies from 5.5 GW to 56 GW (within a system where mean demand is 46 GW). And this is only in one month in one January. Clearly it is therefore difficult to fit in a significant baseload plant such as nuclear power, for at times, in the month of January 2005, all plant except 5.5 GW must be closed down while wind is given priority. The report makes the important point that the plant that has to work in conjunction with the wind is forced into much thermal cycling, and this causes maintenance problems as well as loss of efficiency. The report also mentions the problems in grid control of dealing with such large fluctuations that are not nearly so predictable as consumer demand. This was a point that has been stressed at length by EoN Netz in Germany, and one of the strengths of the Oswald report is that it confirms that what has applied in Germany is likely to apply to the UK even when the wind turbines are spread as widely as possible.

While the report points at the difficulty of dealing with this uncontrollable input, it would be hard, if not impossible, to quantify it entirely on the basis of theory. For that, what would be required would be a simulator of the entire model of the electrical system with grid operators given the challenge of seeing how well they could control it with such a large uncontrollable input. Thus it would seem wise to try to draw on experience of operators at places where there is already a high wind penetration.

The fact that Denmark can only satisfy about 6% of its electricity supply directly from wind, even though the wind turbines provide about 20%, is some indication of the difficulties, but not a particularly accurate one, since presently Denmark has inadequate transmission lines from the windy west to the east. What Denmark does with the remaining 14% of wind output is export it to Germany, Sweden and Norway, the latter country being particularly suitable to absorb large uncontrollable inputs because of its almost total reliance on hydro power, which it only has to switch off to allow power infeed from wind.

More instructive, regarding the practical difficulties of wind, is the fact that although wind turbines in Germany, in 2005, generated only 4.7% of electricity, EoN Netz were already noting the difficulties of dealing with this uncontrollable input, and that already there was an apparent need to constrain infeed from wind.

Another indicator of difficulties comes from the North West region of the USA, where 63% of electricity is supplied by hydro. As mentioned, hydro is superbly flexible because the turbines can be turned on and off at short notice. For this reason the company initially offered to operate in harness with any wind input. However, once wind was supplying 8% they found the difficulties encountered were such that they had to close that offer.

To sum up, the Oswald report shows that even on a theoretical basis there is a limit of about 19% to the contribution of wind to the electrical system, but practical experience so far tends to suggest that difficulties will be encountered before that point. Since the UK is close to an optimum place for capturing energy from wind, this figure of a maximum of about 20% is of wide applicability.

While this Oswald report is very elucidating, and answers the most pressing questions about wind, it will not serve its purpose if politicians, and the various commissions and organizations which advise them, fail to study it in adequate detail, but instead rely on reports from energy journalists and advice from wind energy consultants. For example, on page 16 of the energy newsletter *Renew*, issue 167, there was an accurate if brief report of the salient points from the Oswald report, but it was followed by this editorial interjection: “note that at present there is only about 2 GW of wind capacity in place, and on current plans, nowhere near 25 GW is envisaged, so this really is hypothetical.” The editorial objection seems to be at looking at the possibility of supplying 19% of UK electrical energy demand from wind. This is strange, because in the same newsletter a whole column was given to one of BWEA’s energy consultants, under the column title, “Milborrow goes for 70%.” The said David Milborrow tried to argue that wind can supply 70% of electricity, his column finishing with these words: “The mythology that wind can supply no more than 20% of electricity has been around for some time, and it is time to consign it to history. I am quite happy to line up with Energinet’s 70%.”

Moreover this is a line that *Renew* has allowed Milborrow to pursue freely, for in the Sept/Oct 2005 issue of *Renew*, the cover had the words “Intermittent Renewables? No Problem!” and Milborrow was given two pages to expound on this theme under the title, “Wind variability — why so contentious?” We must hope that those who are responsible for planning our energy future will study reports such as that by Oswald Consultancy, and not rely on second hand reports and advice from independent consultants who act as spokesmen for the wind industry.

CHOOSING THE BEST UNCONTROLLABLE BETWEEN WIND AND PV

by Andrew R.B. Ferguson

The previous paper, *The Limits to Wind Penetration in the UK*, clarified the point that the maximum that wind can contribute to an electrical system is about 20% of the total system supply. It was noted that this is likely to apply not only in the UK but elsewhere. Even that 20% limit is open to doubt on account of the difficulties which are likely to arise in using controllable plant to handle such large daily power changes (reaching 75% of mean demand), but for present purposes, we can accept that wind might manage to satisfy 20% of the total electrical supply.

Wind is an uncontrollable. A point of great importance is that an electrical system has a limited tolerance for uncontrollable input, so if wind, for instance, has already reached the limit of the system's tolerance for uncontrollables, another uncontrollable cannot be added to the system (there can be exceptions, as per the final paragraph). This makes it imperative to choose the best uncontrollable. Within this context, let us ask whether it would make sense to choose photovoltaics (PV) as the uncontrollable, rather than wind.

I am greatly helped in making this analysis by having a friend with a substantial PV array installed on his roof (situated about 50 miles west of London). The array has a rated capacity of 4560 watts (W) and the module area is 26 square metres. He has provided me with output figures for two years, 4089 kilowatt hours (kWh) in the first year, and 4242 kWh in the second year. From these figures we can select 4200 kWh as a benchmark. He also has a meter which shows the electrical flow at any instant in time. Observations make it clear that peak flows are, from time to time, above the rated capacity of the array. From this information we can make these useful calculations.

Annual output = 4200/26 = 161.5 kWh/m^2, or $\underline{\underline{161,500}}$ Wh/m^2 (or power of 18.4 W/m^2).

Peak output = 4560 / 26 = $\underline{175}$ W/m^2.

This is an excellent performance for UK insolation, constituting a 10.5% load factor; perhaps the UK air has become less opaque since insolation was assessed during 1978-87. Anyhow, let us now contemplate — as it will prove to be a useful choice of illustration — putting 8 m^2 of such modules on each one of 20 million roofs (or another arrangement which arrives at a total module area of 160 million m^2).

It seems likely that the whole UK will from time to time be enjoying close to optimum insolation, so the peak output would be 175 x 160 x 10^6 = 28 x 10^9 Wh, or $\underline{\underline{28}}$ GW.

Since we found, when looking at wind, that 25 GW of wind capacity was about the limit for wind, 28 GW is certainly the limit for PV — it may be less because of the difficulty of dealing with the rapid changes which would occur as large banks of cloud obscure the sun.

The annual output from that 28 GW of capacity would be 161,500 x 160 x 10^6 Wh = 26 x 10^{12} Wh, or $\underline{\underline{26}}$ terawatt hours (TWh).

Since the UK electrical supply is about 405 TWh/yr, that means that photovoltaics could satisfy 26 / 405 = $\underline{\underline{6}}$% of UK electrical supply.

There are other reasons for not selecting PV, such as the high capital cost per kWh, and the amount of energy that would go into constructing 160 square kilometres of module, but remembering Occam's Razor, and the motto that it is vain to do with much what can be done with little, let us simply note that it would be unwise to choose a system that might supply 6% of UK electrical supply, instead of wind which might supply 20%.

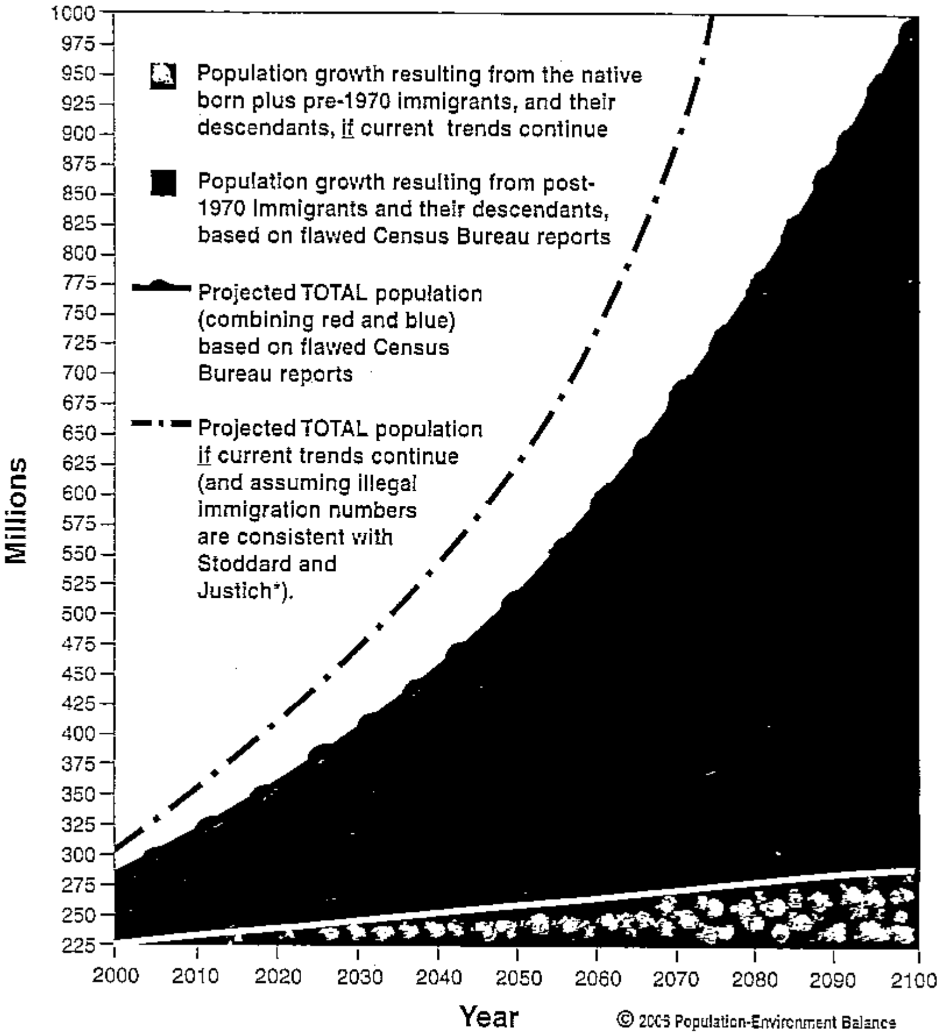
It should be noted that we have been considering the UK. In countries like Australia and the USA, where the use of air conditioning in summer is sufficiently prevalent to ensure a high demand in the middle of the day, it is possible to use PV for peak shaving, that is to say to diminish the extent of the demand falling on controllables during a time when demand is predictably high (though not usually a peak) around the middle of the day.

There are three reasons for including this diagram:

1. A similar diagram was reproduced in what was effectively the first OPT Journal, September 2001. The title then was **USA – One Billion in 2100?** The average annual growth rate then assumed was 1.29%. In the intervening years the situation has grown dramatically worse, and hence the new title.
2. This diagram neatly sums up what Virginia Deane Abernethy set out in the April 2007 issue of the OPT Journal (pp. 24-28), namely that the actual U.S. growth rate is between 1.4% and 1.7%. Note that in this diagram, the block showing the Census Bureau projections assumes a 1.3% annual growth rate, and the dotted line is equivalent to a mean annual growth rate of 1.6%.
3. The USA provides an example of a problem which afflicts Europe too, the difference being that in Europe the growth rates are not quite so fearsome, but the starting position, particularly in the UK, is worse.

U.S.A. – One Billion in 2075

Current Trend of U.S. Population Growth



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