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The Edge of The Abyss

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The past year has provided disturbing new evidence that fossil energy is heading into decline faster than had been expected, climate change is happening faster, and the attendant impacts on food production are already being felt. These are the great issues of our time, and they will interact. This will be a tumultuous century, as competition grows for diminishing resources. The human race will not get through it without fundamental changes of our population size, our living arrangements, our consumption patterns, and our expectations – and probably not without mounting hunger and violence. This paper will summarize how the new information changes the prognosis for this century and deepens the need for a new mindset to deal with it.

THE LESSONS OF 2007

The name of the abyss is energy. People tend to worry about one crisis at a time. We do so at our peril. Right now, the crisis of the moment is climate warming, but the decline of fossil energy will affect more people more seriously than climate change for most of this century. Both will generate a coming crisis in food production, though declining fossil energy will eventually stop forcing the climate warming.

...and the source of the crisis is the growth of human population and consumption. Rising population and consumption led to our profligate use of fossil energy, which in turn has been the principal cause of anthropogenic climate change. Further increase in U.S. and world population will make the crisis worse, as will rising consumption levels in developing countries.

The present era begins with the invention of the steam engine in the 18th Century. That innocent invention, first built to pump water out of mines, soon required fossil fuel. It led to the industrial and agricultural revolutions and to the modern world, but the demand for that fuel has led the world, with gathering speed, into a series of interactive changes that are coming together and leading into a giant crisis new to human experience.

The forces now coming together are

- the astonishing growth of fossil fuel use in the 20th Century,
- the growth of human population, quadrupling in the same period,
- climate warming and rising sea levels generated by that growth, generally recognized as a threat only in the past two decades,
- the imminent decline of those fossil fuels, still unrecognized as a problem by most policy makers,
- the growing shortage of fresh water to meet human needs,
- and – as a consequence of those changes – the prospect that agriculture will be unable to produce enough food to feed us.

Together, those changes are the most important immediate challenge to humankind. They threaten the fabric of modern societies. The threat – still largely unrecognized – transcends all the other problems that transfix our policy makers: terrorism, economic recession or the transitory issues of international politics, and even the threat of nuclear proliferation.

This is not hyperbole. We have recently learned that the crisis is closer than we had thought. Time is running out. It has already run out for those who hoped we could weather it without fundamental changes in the way we live.

The threats we and other creatures face are of our own doing. Our pell-mell pursuit of growth and innovation has led us into multiple dangers. I listed many of them in *The Age of Overshoot.*[1] But the group of changes described above is the proximate threat to billions of humans.

This paper is written to pull those elements together and to sound an alarm. I have written on these issues before.[2] Here, I will focus on the new information that gives them increased urgency.

ENERGY

We are at the end of a bonanza. For over a century, a rising flood of fossil energy has fueled the growth of the industrial world and supported levels of consumption previously unimaginable. The new industrial nations are beginning to participate, but they have arrived on the scene too late to enjoy the bonanza for long. Now, with the evidence mounting that oil and coal are peaking and will soon decline, we face the unwinding of that age of high consumption.

Crude oil production has peaked or will soon peak. The "experts" in government, the oil industry and its think tanks reassured us for decades that there is plenty of oil into some distant future. Now, new data from the "establishment" – i.e. the U.S. Energy Information Administration (EIA) – show that world crude oil production peaked in May 2005. The International Energy Agency (IEA) shows a peak in roughly the same time frame, but its figures lag, and its most current figures do not separate crude oil from other liquid fuels. In November, however, it warned of a "supply crunch" by 2015.

By way of corroboration, the EIA data show that Saudi production peaked in May-September 2005 at 9.6 million barrels per day (mb/d), and the latest production figures (January-September 2007) are 10 percent lower,[3] Total OPEC production peaked in the same period. Even the OPEC Secretariat, that bastion of optimism, has recently, and for the first time, admitted that OPEC may not be able to keep up with anticipated demand, and that it will fall short sometime in the 2024-2048 time frame.[4] That looks too optimistic. It depends upon Saudi Arabia for increasing production, but the Saudis' big field, Ghawar, is in decline.[5] The Saudis have tripled their exploration effort in recent years, without apparent success. (They have had similar bad luck looking for new gas.) President Bush, in his recent trip, pleaded with the Saudis to increase their production but was rather sharply rebuffed. One wonders whether, as some knowledgeable Saudis have suggested, they can't.

Rutledge (see below) reports the leak of a secret estimate by the Kuwaiti oil authorities cutting the official estimate of reserves in half.

Mexico's largest field, Cantarell, is also in decline, and North Sea production is said to be in "free fall". Kashagan, the largest field discovered in two decades, was identified in 2000, and is not expected to start producing for several years, delayed by technical difficulties and political setbacks. Half the major oil producing countries are now experiencing declines. The *Wall Street Journal* interviewed a spectrum of oil specialists; they estimated that world crude production from existing fields is declining 4.5 to 8 percent a year.[6] That would mean a decline of 37 percent to 56 percent in the next 10 years, and there is little hope that new fields can be found and developed to replace that 27 to 41 million b/d.

There may still be another peak, but if so it must be soon, because of that arithmetic, and pumping existing fields harder would simply hasten their decline. The "experts" are now warning of shortages ahead and offering no assurance they will be overcome. Present or recent senior officers of Aramco, Exxon Mobil, Shell, BP, Total, Chevron, Iranian Petroleum, Occidental, the European Union and the IEA have warned that the conventional petroleum reserve estimates are too high and that an oil crunch is upon us or imminent. The "Peak Oil" geologists, long ridiculed, seem to have won the debate.

There is probably much less coal than we thought. The conventional wisdom was that we had "hundreds of years" of coal, and that it would carry us through the distant day when oil began to decline. Now, a German think tank has published an estimate of world coal resources astonishingly more pessimistic than previous estimates: "...in the best case scenario, world coal

production will peak around 2025 at 30 percent above present production." Production in China, the major consumer, will start to decline "within the next 5-15 years." (This is a function of growth. China's coal consumption doubled in the six years 2000-2006. It now consumes 40 percent of world production and is on track to consume more than the rest of the world combined within several years.)

Even in the United States, with the world's largest claimed reserves, "it is very likely that bituminous coal production...has already peaked, and that total (volumetric) coal production will peak between 2020 and 2030."[7]

Those projections come as a bombshell, but two other new studies come to conclusions about as dire. "Hubbert's Peak, the Coal Question and Climate Change", by Prof. Dave Rutledge projects coal and other fossil fuel production (**http://rutledge.caltech.edu)**. His estimates of future coal production are chilling. The global total is 374 to 435 gigatons, which is only 44 to 51 percent of the World Energy Council (WEC) estimate of global reserves; his figure for Russia and central Asia is remarkably low: 16 percent of the WEC figure; and for North America it is 29 to 51 percent of the WEC figure. (He is ambivalent about Montana, as is the German group). He believes that half of all the world's exploitable fossil energy will have been consumed by 2021, which effectively defines peak energy production. That is a very short time frame.

Rutledge goes on to draw some novel and interesting connections with climate change, which I will describe later. He makes the case for moving away from fossil energy before we exhaust it, in order to save some for future use as chemical feedstocks. And he argues for moving now to renewables, particularly solar thermal energy, which can store intermittent solar energy better than most renewables.

Both those studies depart from the conventional way of predicting production on the basis of reserve/resource estimates. They almost dismiss unproven resources and use a variant of the M. King Hubbert peak oil analysis, which has proven more accurate than past techniques, as Rutledge demonstrated in the case of UK coal. The approach is counter-intuitive but it seems to work.

A new National Academy of Sciences report confines itself to U.S. coal resources. It is more cautious than those two studies, but still it would bring the conventional wisdom far down:

> "Despite significant uncertainties in the existing resource estimates, it is clear that there is sufficient coal at current rates of production to meet anticipated needs through 2030. Further into the future, there is probably sufficient coal to meet the nation's needs for more than 100 years at current rates of consumption. However, it is not possible to confirm the often-quoted assertion that there will be a sufficient supply of coal for the next 250 years. A combination of increased rates of production with more detailed reserve analyses that take into account location, quality, recoverability, and transportation issues may substantially reduce the number of years of supply."[8]

"Current rates of consumption" are irrelevant if demand is rising, especially if coal is called upon to furnish energy that is presently supplied by oil and gas. Certain adjustments are in order (as the above paragraph itself states in rather opaque English). Let us assume that demand rises 2 percent per year, as the EIA projects through 2030. That would bring the "100 years" down to 55 years, and "2030" down to 2025. That is a far cry from "250 years". (I would caution that factoring in rising consumption is nearly as misleading as using "present rates," because it portrays a period of rising consumption dropping abruptly to zero. In the real world, the energy decline will be much more prolonged and irregular, with no clear and definite end. But it does give some idea of magnitude.)

All three studies emphasize that the data are very weak, and the NAS report calls for a 10 year study to learn more about the supply.

Coal causes much more pollution, and contributes more to global warming, than oil or gas. I cannot escape a certain grim satisfaction at the evidence that it is declining faster than we expected. That will be good for

the Earth in the long term. There will be less pollution and, more important, less climate warming. We have no assurance that we can sequester much of the 28 billion tons of CO_2 that human activity is presently releasing annually into the atmosphere, and no nation is really trying very hard. (The U.S. Government has just dropped its support for the pilot FutureGen power plant in Illinois because of cost overruns.) But for much of this century, a faster decline will make our problems much worse, because it gives us so little time to make the colossal adjustments that will be necessary to live in the post-fossil fuel era.

Gas resources are in question. In the years of abundance, gas was simply flared in the oil fields, as a nuisance. It came into its own as a clean fuel only in the 1970s. World consumption has doubled since 1980 and is still rising at 3 percent per year.

Gas resources have not been given the hard scrutiny that coal has. They are particularly difficult to predict because it is a gas, because of its history, and because it is not confined to such narrowly constricted conditions as oil and coal. The EIA and the WEC both use the same figure for global reserves: 177 trillion cubic meters, presumably derived from the same official sources. That works out to 34 years if growth continues at 3 percent a year and 40 years if growth slows to 2 percent, as the EIA predicts.

The EIA adds only 18 percent to the proven reserve figure to allow for undiscovered resources, on the assumption that most of the remaining resources are not economically recoverable. The WEC suggests that they will more than double the reserve figure. (This discrepancy is an example of the wide disparities common to energy predictions.) A USGS projection published in 2000 was close to the WEC figure. In this instance, peak oil guru Colin Campbell is not far from the EIA estimate.[9]

Considerable skepticism is in order when reading energy estimates and projections. (1) *Petroleum* can mean different things. Traditionally, it meant crude oil alone, but there is a spectrum of liquid hydrocarbons from tar sands to natural gas liquids, and some sources now call all of them "petroleum." That adds about 15 percent to the total. (2) Definitions and measures of *proven reserves, recoverable reserves, and undiscovered (recoverable) resources* and even *coal* vary from country to country. (3) There is simply a lot we don't know and must guess about. I have cited examples of widely differing projections. To add one more example: the NAS study (above) observed that predictions of U.S. annual consumption in 2030 vary from 50 percent below present consumption to 70 percent above. (4) Most OPEC countries, Russia and the central Asian producers do not give specifics, such as production by field or the way they figure reserves. Saudi Arabia, Kuwait, and the UAE have not changed their estimates of proven reserves since the 1980s, which is close to an arithmetical impossibility. (5) Fuzzy terms such as *enough oil* are common.

Nevertheless, the trends are apparent. The EIA has grown very nervous. At one point recently, it said "The consequences of unfettered growth in global energy demand are alarming."[10] That is a new idea for the EIA. Perceptions are slowly beginning to track reality. Except for a few outliers such as Cambridge Energy Research Associates, there is a fundamental and general shift from the illusion that fossil fuels will take care of our needs indefinitely, to the recognition that an era is ending.

Several realities in energy production aggravate the downward trend.

Global figures conceal national realities. It is customary to speak of "world supplies," but they have little practical meaning. Some 94 percent of world oil reserves are held by governments. Much the same is true of gas and coal. We have reached the end of globalization. As Big Oil learned recently in Venezuela and Kazakhstan, the companies do not control the supplies; the host governments do. Turkmenistan and Russia have cut off gas supplies to neighbors in price disputes (and thereby made the European Union very nervous, since it depends on Russia for nearly half its gas supplies). China has just suspended coal exports for two months to assure its domestic needs. We may anticipate that in the future, those countries will base their energy exports on their own needs, and that the exports may stop as they find their own resources declining, whatever the price.

We can hardly blame them. Countries have controlled their trade at least since Mercantilism. In recent decades the United States, the European Union, Argentina, Australia and Egypt have blocked grain or soybean exports when they found their domestic supply perilously low. Saudi Arabia may find it necessary to keep exporting to earn the foreign exchange to feed and provide goods for its rapidly growing population. Others, like the United Arab Emirates, Kuwait, or Russia, don't feel those pressures.

This is important, because it means that energy scarcities in importing countries can be much sharper and less predictable than would happen under free trade.

It takes more and more energy to produce a given amount of net energy. You must get more energy out than you put in, unless you are trading a less useful form (e.g. coal) for a more useful one (e.g. liquid fuel). The world is beginning to encounter that law. New fields are less accessible and technically more difficult than the old ones. Brazil, for instance, has high hopes for a five to eight billion barrel oil field in the Atlantic – but it lies below 1.5 miles of ocean and three miles of rock. If they can recover that much oil, it will eventually add two or three months' production to gross world output, but it will take a lot of energy to extract it. If they encounter more gas than oil – which is likely at that depth – it may be "stranded"; i.e. be unexploitable because it would take more energy to capture and ship it than it would produce. Similarly, Canada's dirty "heavy oil" (tar sand) deposits are huge, but they are producing only three units of (dirty) energy for every two units of energy (mostly good, clean natural gas) that goes into them. Most of that resource will not justify the energy to extract it – which explains a huge gap between the estimated "resource in place" and the estimated "recoverable resource."

Investors, even sovereign oil companies, will not invest in dying technologies. It may take forty years to develop and amortize an oil field or a coal gasification complex. Energy companies will avoid such investments if they do not think that the resource is there to support that investment. Big Oil has already made that decision about the United States. No new petroleum refineries have been built here for thirty years, and the oil companies are using their profits to buy back their stock, because they cannot see a way to invest them in energy. That in turn means that some "recoverable" reserves will not be recovered.

A technology dies when it is not used. The experts – petroleum geologists, chemists, engineers and technicians – are aging, and the young have little incentive to go into a declining profession.

These factors make a decline self-perpetuating once it begins.

Taken together, and recognizing the many uncertainties, this all suggests that oil has peaked or will peak within several years, that coal will follow within two decades, that gas will peak soon thereafter and that fossil fuels will decline to economic irrelevance, probably within this century. For a century and more, rising demand has led to rising energy production. We now face a daunting prospect: first, a few decades of rising demand chasing diminishing production of fossil fuels, with some help from nuclear energy;[11] and second, a perpetual future of reliance on renewables – the flow of energy from the sun, from the moon (tidal energy), and perhaps a bit from residual heat in the Earth (geothermal).

I dealt with specific renewables in some detail in earlier books. For our present purposes, the salient point is that they will provide much less concentrated energy than fossil fuels now provide. They will be expensive and erratic sources of power. Most will require a great deal of space. Most of them will produce electricity, which cannot fuel aircraft and is ill suited for other transportation needs or for the chemical feedstocks that support industry and agriculture.

CLIMATE

Climate change and its consequences are happening faster than we expected. The Intergovernmental Panel on Climate Change (IPCC) produced its Fourth Assessment, a set of four integrated reports, during 2007. The Summary for Policy Makers, published in November 2007, is an extremely dense 23 pages of text and graphics, but it is worth reading (www.ipcc.ch/). In essence, it shows increased confi-

dence, compared with earlier versions, in anthropogenic climate warming. It reports an acceleration of the rise of sea levels. Most of the stabilization scenarios envisage peak CO_2 emissions between 2020 and 2060, with emissions in 2050 from 20 to 60 percent higher than in 2000. Those scenarios would raise global average temperatures 3.2 to 4.0˚ C above pre-industrial levels, and sea levels 0.6-2.4 meters. Greenhouse gases would stabilize sometime between 2100 and 2150, and sea levels later (Table SPM.6). The Summary attempts to describe the impacts (sharper than suggested in earlier reports), and how to ameliorate them (which shows such a range of opinions as to be of very little guidance.)

...and change is swifter than the IPCC Summary said. What the IPCC Summary didn't say is perhaps more important than what it did say. There has been dramatic recent evidence of glacial melt in Greenland and West Antarctica, and of unparalleled melting of the Arctic pack ice last summer, which meant that the region absorbed more solar heat than anticipated. (The Northwest Passage was suddenly ice-free.) The IPCC said that it did not take those developments into account, because they were too recent for detailed study. In the tropics, new evidence of the vulnerability of the Amazon Basin to droughts suggests a potential feedback that would swiftly turn it into a source rather than a sink of CO_2 and further drive global warming.[12] The Summary, under political pressure, omitted data from the full report – including a table (WGII TableTS.3) that, in the words of *Science*, "makes it clear that substantial impacts are likely to arrive sooner rather than later." A 2˚ C global temperature warming by mid-century – which even the "optimistic" scenario foresees – would cause a 20 to 80 percent loss of Amazon rainforest, "increasing drought in mid-latitudes and semi-arid low latitudes, placing one to two billion additional people under increased water stress, ... decreases in low-level crop productivity, as in wheat and maize in India and rice in China, among other pervasive impacts."[13]

That table warns that a 2˚ C to 3˚ C temperature rise, which looks likely before 2100, would commit the world to a delayed melting of the Greenland ice cap, which in turn would eventually flood "much of South Florida, Bangladesh and major coastal cities."

This has led *Science* and various scientists to warn that giant consensus exercises such as the IPCC may have outrun their usefulness, and that there is an urgent need for focused groups exploring things that the IPCC process has largely ignored, such as the possibility that the climate system is hypersensitive to greenhouse gases.

The new evidence confirms what I said in *The Age of Overshoot* about climate, but brings it closer.

The energy specialists suggest that things may not be that bad. The IPCC report preceded the new energy timetables I described above. In fact, it specifically said that it did not anticipate that any energy shortages would occur in this century sufficient to cause them to change their conclusions.

That is an example of the failure of communication between specialists in different fields. The energy crisis may offer some hope about climate warming, a few decades hence. Rutledge used a model from the IPCC itself to run a projection of how his energy projections would affect climate change. With unrestricted use, he projected emissions to start declining in 2020, to near zero by 2130. On the same assumption, atmospheric CO_2 concentrations would peak at 453 ppm in 2070 and taper down to 380 (about the present level) by 2175. (Apparently he was describing CO_2 and not its equivalents, and from energy sources alone, not all sources.)

In sum: the new evidence about climate change suggests that climate is more sensitive to emissions than the models projected, and that its impact will be at least as severe as expected, but these new energy studies point to the possibility that anthropogenic climate change may be less long-lasting than the IPCC expects.

WATER

Water tables are falling and rivers running dry in many or most countries, including the United States, China, India, and Pakistan.[14] Most water goes to irrigation, and irrigation has expanded to feed growing populations. New reports have documented the consequences, including the spread of deserts.

Data on fresh water are at least as shaky as energy

data. The most widely quoted world figure is a 1997 study done for the UN Commission on Sustainable Development. It may be dated, but even then it estimated that one-third of the world's population suffered "water stress" and that the figure would rise to two-thirds by 2025. One-fifth of the world's population did not have access to clean fresh water, and half the population of less developed countries suffered from water- and food-borne diseases. It described population growth as first among the causes of the problems.[15]

In the United States, we are seeing shortages affecting urban supplies in California and a widely publicized shortage in Atlanta, GA. Perhaps we should call it a "longage" of demand (in Garrett Hardin's memorable phrase), not a water shortage. Atlanta's metropolitan population has been growing forty percent a decade.

... climate change will make it much worse. Atlanta may have worse problems to come. Climate models agree that climate change will probably lead to a drier climate in the southeastern and southwestern United States.

The recent IPCC reports simply confirmed and intensified the expectation that change will have worldwide consequences for fresh water. There will be more droughts, more damaging floods and storms, higher temperatures and thus swifter evaporation, faster runoff of mountain streams and therefore a more erratic water supply. That prospect is a particularly desperate one for the already arid zones in the tropics.

FOOD

Agriculture will not be able to support the present human populations. The basic meaning of "overshoot" in *The Age of Overshoot* is that modern commercial agriculture has enabled human populations to grow, at least momentarily, far beyond the populations that can be supported in the absence of fossil energy.

Fertilizer is the most obvious component of that equation. In the pre-modern order of things, nitrogen was created to support plant growth only through microbial nitrogen fixation (usually associated with legumes), or by the occasional lightning bolt. Modern nitrogenous commercial fertilizer is made by using natural gas, or coal, and petroleum to pull molecular nitrogen from the air and add hydrogen. It will become more and more expensive as fossil fuels decline. An electric arc can be used to create nitrogen compounds – this is analogous to a lightning flash – but it takes a lot of electricity. After fossil energy, perhaps we will use renewable energy to run that process, but otherwise our descendants must rely on green manuring or animal manure to replace the nitrogen harvested from the fields. That means that some arable land must be devoted to those uses rather than to crops for direct human use.

Phosphates and potassium fertilizer are also necessities, and they pose somewhat different problems. Both are mined, not manufactured, and we need a lot of them. Known world reserves of phosphate amount to 88 years of current consumption. (We can use that term in this case because, except for Africa, the world is applying roughly as much fertilizer as the land can use.) For potash (the source of potassium), it works out to 222 years. The industry hopes that unproven resources will double or triple those figures. There is a problem here of long term sustainability, but for a century or more the problem will be moving the fertilizers where they are needed. Some 64 percent of known phosphates are in Morocco, and 50 percent of the potash is in Canada.[16] About 150 million tons of those fertilizers are shipped annually, much of it for long distances. That will become much more expensive and laborious as energy costs rise. Some time toward the close of this century, we will probably be shipping it under sail. Indeed, that used to happen. But not 150 million tons.

Fossil energy is also used to produce pesticides. Substitutes must eventually be found.

We will probably revert in some degree to draft animals. They will help to fertilize the fields, but they also need grazing acreage. Early in the 20th Century, that took about one-fifth of arable land, which must be deducted from current food producing acreage. Most draft animals have disappeared from the industrial world. As one side issue, we may not be able to breed them as fast as the need for them rises.

Worldwide, some of the best land has been diverted from food production to city sprawl, industry and

roads. Only part of that can be reclaimed. Desertification is engulfing arable land in China, central Asia and Africa.

Beyond that, agriculture must contend with climate change. I have described the weather we must expect. And we must subtract from potential production the arable land that goes under water as sea levels rise.

On the plus side, in the temperate zone, there will be some benefit from higher CO_2 levels, which plants use. Also on the plus side, we have learned a great deal about agronomy in the past century, though much of it may not be applicable to this one. (I'll come back to that.)

What agricultural yields may we expect in the post-fossil era, when those changes have happened? This is hardly the kind of prophesy one can utter with much confidence, but I will offer a rough indicator. U.S. corn (maize) is a useful surrogate for grain crops, which are some 70 percent of the total. It is the major single crop in the United States, the source of most livestock feed, and our biggest agricultural export. Early in the last century, before commercial fertilizers were generally available, U.S. corn yields were about 25 percent of present yields. By the 1950s, when commercial fertilizers, pesticides, mechanization and modern plant breeding had just gotten under way, they had risen to 40 percent. The overall change for all crops may have been somewhat less dramatic, since corn has been particularly responsive to fertilizers and plant breeding.

That suggests that yields in the industrial world may be 25 to 40 percent of current yields after the fossil fuel era, assuming that productive systems do not collapse in social disorder. Yields will be higher because we will know more about plant breeding than we did then, but they will be lowered by climate change and the weather patterns described above.

Total food production will be reduced somewhat more because of the losses of arable land I described above.

Those calculations are of less use in the poorer countries, given their multiple conditions and histories (see below).

POPULATION AND DEMAND

Many of us have described the history and probable future of population growth, on many occasions. The new evidence (e.g. the UN 2006 population projection) does not much change that picture, and it is not hopeful.

The most important questions before us now are: how many people will the world be able to support in the changed conditions described above? And how will different population futures affect the ability of different countries to make the immense changes needed to live in the new world? I will try to answer the first question now and the second question later.

The reason for my horseback estimates of food yields in the post-fossil era was to provide some sort of answer to the first question. That rough calculation suggests a global figure somewhat lower than 25-40 percent of current population, to allow for loss of arable land and its diversion away from food crops, but there will be dramatic differences among countries and regions, depending on their present conditions.

Another approach – and equally simplistic – would be to ask: how many people were there in 1950? The fact they were alive testifies to their having food, but not necessarily enough. (Hunger was a problem then, and it is a problem now, though the location of acute hunger has tended to move from China and south Asia to Africa.)

In 1950, the LDC (less developed countries', i.e. poorer countries') population was 1.1 billion (excluding China), or 27 percent of the present population. China's 1950 population was probably over 500 million, or some 40 percent of the present population. (Any more precise estimate is dubious.) The industrial world had 814 million people then, or 67 percent of the 1.2 billion it has now. (Europe was the principal food importer then, which helps to explain that high percentage.) World population in 1950 was 2.5 billion, 38 percent of the present population. That percentage, interestingly, is within the range of future food production I gave above. I tried my hand at making more detailed estimates and concluded that they did not give me much more confi-

dence about the number. There are simply too many unknowns and variables involved.

In practical terms, those percentages are probably too high. They don't take climate change into account. Moreover, much food now is shipped from several exporting nations to many food-deficit ones. Producers will tend to hoard when supplies are short, and it will become harder and harder to move large volumes by ship, so food will probably be less evenly distributed by the end of the century than it is now. And the 2.5 billion assumes that food production will not be hampered in the future by increasing political turbulence and wars, which is an optimistic assumption.

The demographics are not very hopeful. **The large traditional grain exporters – the United States, Canada, Australia and Argentina – are the best off.** Right now, for example, the United States' food consumption is so high that we might be able to feed the present population when the commercial fertilizers are gone – if we halve our grain use per capita by slashing our consumption of meat and dairy products, stop exporting grains and give up imported luxury foods. That calculation leaves out the impact on the poor abroad who depend on U.S. grains, it ignores the question of how to transport the food, and it provides no margin of safety. A safer goal – which would allow loss from climate change – would be the 150 million people (less than half the present population) we had in 1950. The problem is that we won't have the present population. We are growing fast because of high immigration and the new immigrants' high average fertility.

If it were not for immigration, Europe's population would decline roughly in line with food production. (For over three decades, it has been a net food exporter.) Using Italy as an example – perhaps not the best example, since it runs a modest deficit balance in food trade – I once pointed out that its population would decline to 14 percent of the present level by 2100 if there were no immigration, but that of course would mean the gradual disappearance of the Italian people. It would be 40 percent even if Italy returns to replacement fertility.[17] That might be enough to feed its people, but it does not provide a cushion for climate change. (There is a possibility that the Gulf Stream will weaken enough to plunge Europe into a frigid climate, but the IPCC does not think it will happen in this century.)

Italy's (and Europe's) problem, again, is immigration. The UN 2006 "constant fertility" projection comes up with Italy's 2050 population 86 percent the present size, even with the current low fertility, because it projects net annual immigration in the 135-200 thousand range. That is much less than recent immigration, but it is enough to tilt the food balance against them. I toss that in to provide a dramatic example of the impact of immigration on population size and, in this case, on food per capita. In fact, things are worse than that. Italy's population has been rising in recent years because of immigration, despite a fertility rate far below replacement level for three decades.

In the same constant fertility projection, the UN projects only a 9 percent decline for Europe as a whole by 2050, because of immigration. That may take care of the aging problem, but nothing else.

Those countries heavily dependent on food imports, even the rich ones, are in a much worse situation. As examples, I would offer Japan, the Republic of Korea, Taiwan, or Singapore. Their populations are declining, but they are so far from self-sufficiency in food that they will face catastrophe if food imports dry up in an increasingly food-short world.

China and India – nearly 40 percent of the world's people – are uniquely sensitive to the rate of decline in world energy. Right now, they are half-industrializing, half-subsistence societies. They both depend on their own coal and on heavy petroleum imports, and both are industrializing on the U.S. energy-intensive model, which is the worst possible model for the coming era. China has achieved industrial-country agricultural yields by using more fertilizer per hectare than the United States. It will face a sudden and dramatic decline in food production if its coal supplies are anywhere near as limited as the new German study suggests. When it started the "one child" program, China's leadership stated the goal of bringing population down eventually to 750 million. They have grown silent about that as the difficulty became obvious, but they would do well to re-state the target at 500 million.

The poorest countries, many of them in sub-

Saharan Africa, never got out of the abyss. They are already stalked by hunger. Climate change will make it worse, but energy shortages will have limited relevance to countries that use very little commercial energy. Sub-Saharan Africa has 12 percent of the world's population but uses less than one percent of the world's commercial fertilizer. Its population has risen from 177 million in 1950 to 742 million now. By 2050, the UN projects an increase to 3.2 billion if fertility stays stuck where it is, or 2.03 billion in the medium projection (which assumes a dramatic decline in fertility.) I don't think that either figure is possible. Hunger, disease and more turmoil will stop the growth, because no conscious policy could stop it in time simply by reducing fertility. Percentage-wise, those are the fastest-growing countries. The land has been badly degraded and is prone to desertification. The Sahara is expanding south across the Sahel. Hunger will probably get much worse. Their governments are mostly non-functional, and in some of them the writ of government does not extend much beyond the capital or where the soldiers are. The increasing certainty of climate change and the concomitant heating and drying of the tropics, coupled with population growth, are turning desperation into despair. Aid from donor countries has been declining, and it will presumably disappear as the donors themselves face worsening energy and food problems.

What can one say?

How long does it take to turn population growth around? For the United States, I have run projections of "the two child family," which would represent a decline in the total fertility rate to 1.5. That in turn would lead to a gradual population decline to half the present level in 2100, with annual net immigration of 200,000.[18] But it has to start happening, and right now immigration is about five times that figure, and fertility is rising.

As the Italian example suggested, fertility in much of Europe is on track to bring population down in some general accordance with the prospective decline in food production. But that would work only in combination with net immigration near zero, which is not happening.

As to China: achievement of the 500 million figure in this century seems out of reach, barring rising mortality. Even with a forceful population program, they are not on that track. The UN 2006 "low" estimate of Chinese population puts it still over 1.2 billion in 2050. Even my 500 million target may be too high to sustain the country's food intake by 2100, because pollution, overuse of water supplies and desertification are rapidly eroding its ability to produce food. China is a net food importer now, but not a large one, given its size. How swiftly food production declines will depend on how much coal it has left.

For those countries heavily dependent on food imports, and for the poorest nations, I cannot envisage a scenario that does not involve major famines and intensified emigration of those who can migrate. And that in turn makes a solution harder in the United States and Europe.

In sum: The present trends will raise mortality and thus accomplish, brutally, the reversal of population growth that we could not achieve humanely and voluntarily. The crisis has come too close. Turning population growth around once seemed a way of escaping the abyss before us, but the time frame is now too short for escape. We must concentrate on mitigating the damage.

It is not an appraisal I like to make.

HOW DEEP THE ABYSS? AND HOW WIDE?

The abyss is a multiple of many changes, with varying intensities dependent on what if anything we do to cushion the fall.

– It will show itself first in rising prices and diminished spending power for most people. That seems to be happening now. Witness the recent crude oil and gasoline price rises. Energy and food prices have outstripped other consumer prices in the United States. The Food and Agriculture Organization (FAO) international price index for 60 foods rose 14 percent in 2006 and 37 percent in 2007. There have been food riots in nine countries, driven in part by the U.S. corn-to-ethanol program (see below). The price rises will stop temporarily if there is a

worldwide depression, but the general deterioration in standards of living will intensify.

– Labor productivity will diminish in a long curve as we go back by degrees to labor-intensive production processes. This will depress wages and (I hope) the income of the rich. With the decline of mechanization, labor will necessarily move back into agriculture.

– Food production, not just production per capita, will decline with climate warming and the decreasing availability of fertilizers.

– As food production falls farther and farther behind demand, the areas of hunger will expand. This will lead to more struggles and wars over food and land, frequently disguised as ethnic or religious conflict (such as we already see in Africa), and to intense migratory pressures, far beyond what we are presently seeing.

– For millennia, even with tiny populations, humans have cut down forests for fuel and timber and to open up arable land. The fossil fuel era briefly reversed that trend, but it has resumed in the poor countries. We will log the forests again, savagely, to fill the gap left when that era ended. After timber, we will start harvesting bushes and grasses, as happens even now in poor countries. Future climate warming will be driven both by the carbon releases and the loss of the forests, and our descendants will live in a stripped world.

– Huge urban complexes are inefficient and will be unsupportable. There will be pressure to move to more efficient small cities and towns and the countryside, but what happens to all those people? I'd better leave that unsaid.

– Rising seas will generate an ongoing effort by coastal residents to find new homes higher up, in the face of resistance from the upland residents.

– Most of the things we routinely use will not be available. The world will change into a bizarre mix of traditional living and working arrangements and post-modern high-tech ways of saving and using what energy is intermittently available. We will live with much less energy, with cold in the winter and heat in the summer, with much less food and the prospect of more famines in the world. It will be much less comfortable than it has been, but we will not have that alternative.

We can imagine this only vaguely and in bloodless outline. Certainly, the process will differ in speed and intensity in different countries and regions, generating conflicts.

How long will it last? Perhaps forever. Even at best, we won't come back to the rich highlands of energy use, even if we develop some future technologies such as workable nuclear fusion that will mitigate the energy transition. But we may come eventually into a new balance. In the 1930s I lived on farms that were just beginning to benefit from modern devices such as railroads and automobiles. It took more work than moderns are used to, but it was quite livable. And I have visited Amish communities that follow traditional practices by choice, and they had rich farms.

The key qualification for that success, aside from an energetic and dedicated labor force, is a favorable ratio of land to people. Neither this country nor the world can go back to it with present populations. The only way to get there – the only fundamental solution available to us – is population reduction, whether voluntarily or through rising mortality.

At worst, we should consider the hundreds of years of Dark Ages that followed the collapse of Rome – and that happened without an energy crisis, though it may have been hastened by desertification and the collapse of Rome's north African granary.

NATIONAL POLICY ON THE EDGE OF THE ABYSS

To hear our potentates, politicians and pundits, there is no problem. Growth is a very pleasant experience for those who profit from it. Those orators promise

growth, not restraint. What do the communiques from every international economic meeting call for? Faster growth. To admit that the Earth is finite and that we have exceeded its carrying capacity is to admit that we must give up that pleasant trip. Their solution is denial. Deny there is a problem, or offer easy fixes, and perhaps one can continue to believe in perpetual growth. And that is what they are doing.

There is the dawn of recognition that something is wrong. In *The Age of Overshoot*, I discussed the rift between scientists who see the limits to growth and the businessmen, politicians and economists who do not. In 2007, some politicians came close to crossing that rift.

... but not enough. Which of our Presidents has raised doubts about population growth? (This one may surprise you. It was President Nixon in 1969, and that was when our population was 200 million, not 300 million plus.) Of our leading political figures, only one, Al Gore, has raised climate change to the importance it deserves. He is not an avowed candidate for any office, and even he has not advocated a U.S. population policy.[19] Yet our CO_2 emissions have been rising in lock step with population growth. Some of the would-be Presidents presently criss-crossing the country are talking about climate change. But none of those people have yet dared to take on the energy transition, or made the connection between population, climate and food, or suggested that we must reverse growth, not encourage it.

The Clean Energy Act of 2007 (now law) and the Climate Security Act of 2007 (S2091, now before the full Senate) are attempts to address climate change. Neither Act begins to touch the problems. The Clean Energy Act would set higher automobile mileage standards – in 2020! S2091 actually states long term targets for carbon emissions, but despite the rhetoric the proposed actions are far from enough to reach the stated targets and woefully short of what is needed to cope with climate change or the energy transition.

I can understand why. We are used to horse trading among interest groups, when clear national policy changes are needed. I have serious doubts that any political system yet devised could handle a set of changes as fundamental, as widespread and as painful as those described above. What do we do when we need leadership, but the last thing we need is leadership in the wrong direction?

The sponsors of the current legislation are trying to mobilize the votes for a new idea – dealing with climate change – among legislators with a traditional national mindset in favor of growth. The legislation that is needed would not pass. The environmentalists who call for tougher laws do not yet have that clout, and they themselves are silent about growth.[20]

Immigration drives population growth, but U.S. policy makers do not make the connection. Instead, both parties treat it as a tool to appeal either to Hispanics or conservatives. And they equivocate. As a consequence, our immigration policies are largely the result of American businesses' interest in cheap labor. Since the 19th Century, they have sought cheap labor abroad to counter labor's pressure for higher wages. When we had 60 million people, we could use that labor. Now, we don't need it, but those employers call it racist to challenge their immigration agenda. They have found an unlikely ally among idealists who believe in One World and sympathize with poor immigrants – even while they ignore our own poor and our children's future. Greed has seduced Charity.

TOWARD A NEW MINDSET

In *The Age of Overshoot*, I catalogued and italicized the things that must be done if this century is not to be a catastrophe. Here I will confine myself to the broad changes in attitude and direction needed if we are to do anything about it.

"Business as usual" is not an option. The Bush administration seems to believe that we have a choice between addressing climate and energy problems or pursuing economic growth. We behave in international climate meetings (such as the recent one in Bali) as though this were a zero-sum game – as if we must persuade China or India to address the problems, so we can do less.

What is good for the world is good for the United States. It is still good for us even if we cannot bring everybody else along. We must stop pretending that growth is prosperity. Our economy will be the loser if it is based upon intensive energy use when energy starts its

decline. We will wind up in collapse when the easy energy is gone, and we will have intensified the world-wide crisis.

We cannot perpetuate the present. The corn-to-ethanol subsidy has been a disaster. It is diverting billions of dollars into a project that would be unsustainable. It absorbs one-fifth or more (the proportion is rising) of our corn crop to produce an automobile fuel that

- is less efficient than diesel or gasoline,
- is so corrosive it must be shipped by special tank cars,
- tends to clog automobile engines when mixed with gasoline,
- has led to a doubling of the price of corn in the United States,
- has cut into our feed grain supplies and raised the price of meat and chicken,
- has diminished our exports and caused food riots in Mexico,
- has diverted 19 percent of our soybean acreage to corn this year, raising world soybean prices and hastening forest destruction to plant more soybeans in Brazil.

And on top of all that, there is a hot debate among scientists as to whether ethanol produces any net energy above the energy that goes into making it.

That is precisely the wrong way to address a tight petroleum market and the energy transition. It happened because the Bush administration wanted to show that it was doing something for the American motorist – and incidentally because it pleased one powerful part of the farm lobby.

The energy giants are talking up biofuels generally as a replacement for oil. That too is either a hoax or profound arrogance. A few biofuels such as used cooking oil are now wasted and can usefully be converted to diesel fuel, but most biomass is already being used in its solid state, as fuel or farm mulch. Wood is the ancestor of all our fuels, and solid biomass can fuel generators. Converting solid biomass to a liquid to drive vehicles entails a large energy loss, like making synthetic gasoline from coal. In an energy-short world, the only excuse for it is our passion for automobiles. The rich can afford it, but they are taking food and energy from the poor. Biofuels will become a benign substitute for oil only when populations have dropped so low that there is no pressure on the land. Don't wait.

We must accommodate change. Like King Canute, we are trying to hold back the tide. Congress wasted weeks trying to shore up the automobile culture with those weak energy and climate bills and the ethanol "solution." It could better have set graduated punitive taxes on fossil energy use and CO_2 emissions; the entire economy, not just the auto industry, would have set to work saving energy to offset the higher prices. In the process, it would have worked its way to a different economy adapted to the new realities.

It is clear by now, from European experience, that wind and solar power can be fed into existing systems only up to about 20 percent of those systems' average load; after that, the irregularity of the add-ons becomes unmanageable. However, that power can be used off the grid in many ways. Even interruptible power can find its uses, particularly when consumers come to recognize that renewables may pay off better in the long term than fossil systems that may run out of fuel before they are amortized. The carbon tax I proposed above would, in effect, subsidize renewables by making fossil energy more expensive, but it would not prejudge the decisions. That would be up to the market and the specialists.

As energy prices rise, other prices will rise. It will be much cheaper to build what we can of the new technologies while energy is relatively cheap.

We must address demand. We must bring population levels into balance with our natural support systems. The biosphere that supports us is a remarkably complex, interacting system. We have behaved since the start of the Industrial Revolution as though it were irrelevant to our well-being. We didn't learn to adjust to it the humane way, with lower fertility (and, in the United States, lower immigration). Nature will do it the hard way, through famine and pestilence.

This is the one lesson we do not hear, even from most of the people who offer "solutions". There is no debate about fertility in this country. The immigration debate touches on every aspect except the most important one: its impact on population growth.

Save energy. A declining population, and policies

such as the carbon taxes mentioned above, will save fossil fuels. As Rutledge has pointed out, we should save them for fertilizers, pesticides and transport to slow the decline of food production and give world population more time to adjust. The fertilizer will be very expensive, but we will be desperate enough to pay the price.

I will offer one major example from *The Age of Overshoot* as to how to save fossil fuels. We could cut U.S. future energy consumption, probably below the European level, by changing our zoning and building codes to promote public transport, mixed use development, and the orientation and design of new buildings to capture and hold solar energy. That would pay immediate and rising benefits. Purchasers would welcome it.

Start now to address coming problems. The Green Revolution was based on plentiful water and fertilizer, which the 21st Century will not have. Our agronomists should turn to crash programs to develop crops that tolerate more heat or salt water intrusions, that can survive droughts and rebound from floods. Most important, even if it is still only a dream, the long search for nitrogen-fixing grains to replace commercial fertilizer should be intensified.

Similarly, in energy, research on fusion energy is among our highest priorities. I know nuclear physicists who doubt that we will find a way to achieve it. But if we did, it would provide a major new source of reliable electricity for the future. It would not solve the problems caused by population growth or global warming, but it might ease the energy transition.

BEYOND THE ABYSS

Those efforts are worthwhile even if there is no painless solution. But there comes a time for most people when hope fails. At that point, they will stop trying to cope and will turn instead to a philosophy of *carpe diem*, or sink into a blue funk. I hear those voices. That sort of defeatism can spread very quickly, and it would be the end of any hope of cushioning the descent.

This all sounds profoundly pessimistic. Perhaps. But pessimism is measured by how optimistic you were. If we have been unrealistically optimistic, what I am offering is simply realism. I have not, after all, predicted the end of the species, as some others have. I have simply said that we are heading for a time of immense troubles and inevitable population decline. Soon.

This is hardly a new thing on Earth. Periods of turmoil and even starvation have lasted longer than the brief golden ages of general prosperity – in part because populations have regularly procreated fast enough to wipe out the benefits, per capita, of new techniques and new resources.[21] They have done it before. It is likely that we will do it again. The difference this time is the scale, the difficulty of getting off fossil energy and the damage we have inflicted on the Earth before the consequences caught up with us.

It is not pessimism to recognize that cycle in the human condition. It reflects our genetic predisposition, described by Charles Darwin, to over-breed. What I have suggested is that we try to learn to break the cycle. **Perhaps, after this coming debacle, there will come a time when people have learned that they must live in harmony with the Earth.** That would be a major advance in human perceptions. Right now, we need to recognize the coming decline and its consequences, rather than denying that the age of consumerism will end. We cannot avoid the decline, but perhaps we can learn something from it that future generations can use.

That realism must inform our policies – even those policies such as immigration where we presently deny the connection. Our government, at least in theory, responds in some degree to popular feelings. It must hear the message that the public recognizes our changed circumstances, and that politicians do not need to promise the impossible to be re-elected. I leave it to a later chronicler to say whether that message will get through in the face of demands for growth from those who finance our election campaigns.

NOTES:

I am indebted to Andrew Ferguson, Director of Research, Optimum Population Trust, UK, and to Walter Youngquist, petroleum geologist, for their comments on the draft of this paper. The conclusions I reach, of course, are my own.

1. *Valedictory: The Age of Overshoot* (NPG, Inc., May 2007). Earlier, I dealt with them at length in *Juggernaut: Growth on a Finite Planet* (Seven Locks Press, 1996) and *Too Many People (Seven Locks Press, 2000)*.

2. *The Collapsing Bubble*, (Seven Locks Press, 2005), "Peak Oil: Are We There Yet?" (NPG FOOTNOTE, Negative Population Growth, Inc, Alexandria, VA, November 2007), and "Peak Coal" (NPG FOOTNOTE, December 2007). Unless otherwise cited, data in this FORUM are drawn from those reports. Texts of the FOOTNOTES and of *The Age of Overshoot* are available from NPG or at **www.npg.org.**)

3. EIA Monthly Petroleum Report, November 2007 (released 12-12-07, Table 1.2 "OPEC Crude Oil Production (Excluding Lease Condensate)".

4. OPEC Secretariat, *OPEC Review*, December 2007, reported on Dow Jones Newswires, 2-2-08, 8:27 am.

5. Matthew Simmons, *Twilight in the Desert*, (John Wiley, 2004). Go to **www.simmonsco-intl.com**, or do a web search on "Matthew Simmons" for his general criticism of official optimism on oil resources. In the *Atlantic*, 11-07, James D. Hamilton mapped the declining oil pools at Ghawar.

6. *Wall Street Journal* 1-17-08.

7. Dr. Werner Zittel and Jorg Schindler, "Coal: Resources and Future Production", Ludwig Bolkow Systemtechnik GmbH, Ottobrun, Germany, Final Version 7-10-07, at **www.energywatchgroup.org**. Summarized in NPG FOOTNOTE "Peak Coal".

8. NAS/NRC, National Academies Press, "Coal: Research and Development to Support National Energy Policy," 2007. Executive Summary p.4.

9. *The Collapsing Bubble*, Chap. 2, Note 9.

10. EIA, *World Energy Outlook 2007*. The figures are from Table 44.

11. "Conventional" nuclear power such as we now use faces a resource problem similar to that of fossil fuels. Uranium is widespread, but the concentration declines logarithmically. The price is already rising fast, and there are no reliable estimates of the cost in money and energy to extract it from sources poorer the present veins. Proposals to recover it from the sea are simply speculative. The concentration in the oceans is about 1:10,000,000th that of current ores (per K.S. Deffeyes, *Beyond Oil: The View from Hubbert's Peak* [New York: Hill & Wang, 2005].)

Other proposals to extend the resource include the breeder reactor and nuclear fusion, but after decades of effort neither has been made to work.

12. *The Independent*, London, 7-23-06, citing studies led by the Woods Hole Research Center.

13. "How Urgent is Climate Change?", *Science*, Nov. 23, 2007, pp. 1230-1231.

14. For a dolorous catalogue, see Lester Brown, Earth Policy Institute, News Release 7-24-07, WATER TABLES FALLING AND RIVERS RUNNING DRY.

15. See *Too Many People* Chapter 5 for a water summary and citations.

16. International Fertilizer Industry Association website, **www.fertilizer.org/ifa/statistics.**

17. L. Grant, NPG BOOKNOTE "The Wrong Apocalypse",1999. The figures would be slightly different if recalculated today, and the comparison with the UN 2006 is also slightly less than precise because of different assumptions about mortality.

18. *The Collapsing Bubble*, Figure 2, p.66.

19. Gore has addressed third world population growth with eloquence. See *Earth in the Balance* (New York: Houghton Mifflin, 1992).

20. See Fred Krupp, Environmental Defense, letter to the editor of *Science*, 9/28/07, p. 1864.

21. Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (New York: Viking, 2004), summarized in my NPG Booknote May 2005.

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