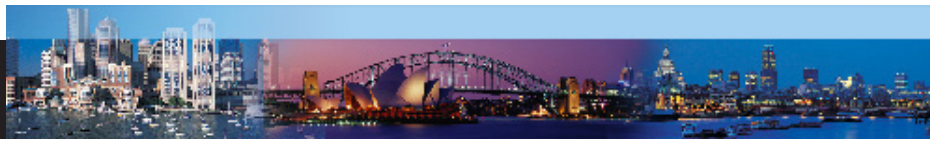
GMO

QUARTERLY LETTER



April 2013

The Race of Our Lives

Jeremy Grantham

Summary

Our global economy, reckless in its use of all resources and natural systems, shows many of the indicators of potential failure that brought down so many civilizations before ours. By sheer luck, though, ours has two features that might just save our bacon: declining fertility rates and progress in alternative energy. Our survival might well depend on doing everything we can to encourage their progress. Vested interests, though, defend the status quo effectively and the majority much prefers optimistic propaganda to uncomfortable truth and wishful thinking rather than tough action. It is likely to be a close race.

The Fall of Civilizations

The collapse of civilizations is a gripping and resonant topic for many of us and one that has attracted many scholars over the years. They see many possible contributing factors to the collapse of previous civilizations, the evidence pieced together shard by shard from civilizations that often left few records. But some themes reoccur in the scholars' work: geographic locations that had misfortune in the availability of useful animal and vegetable life, soil, water, and a source of energy; mismanagement in the overuse and depletion of resources, especially forests, soil, and water; the lack of a safety margin or storage against inevitable droughts and famines; overexpansion and costly unnecessary wars; sometimes a failure of moral spirit as the pioneering toughness and willingness to sacrifice gave way to softer and more cynical ways; increasing complexity of a growing empire that became by degree too expensive in human costs and in the use of limited resources to justify the effort, until the taxes and other demands on ordinary citizens became unbearable, so that an empire, pushed beyond sustainable limits, became vulnerable to even modest shocks that could in earlier days have been easily withstood. Probably the greatest agreement among scholars, though, is that the failing civilizations suffered from growing hubris and overconfidence: the belief that their capabilities after many earlier tests would always rise to the occasion and that growing signs of weakness could be ignored as pessimistic. After all, after 200 or even 500 years, many other dangers had been warned of yet always they had persevered. Until finally they did not.

The bad news is that as I read about these varied scenarios – and I have missed listing several – they all appear plausible and each seems to be relevant to several earlier collapses of empires and civilizations both large and small. Very recently, one of these scholars, William Ophuls, wrote a new book, *Immoderate Greatness*[1] (a quote from Gibbons's *Decline and Fall of the Roman Empire*), with the subtitle *Why Civilizations Fail*. It is a straightforward summary and synthesis of all of the ways to fail in 70 small pages, yet with extensive notes and references. It is written in remarkably accessible, simple language and divides the causes of failure into six categories. Unfortunately, all six seem to apply to us today in varying degrees, and where one factor might be manageable – although often has not been – he makes the chances of our managing all six seem slight. It is persuasive and needs to be read. It takes about two hours.

[1] Published by CreateSpace Independent Publishing Platform (December 28, 2012). It costs just $5 on Kindle. Unfortunately, I receive no royalties.

William Ophuls's conclusion is that we will not resist the impressive list of erosive factors and that, in fact, we are in the fairly late stages of our current civilization's race for the cliff edge with nothing much to head us off. His study of history leads him to believe that civilizations are actually hard wired to self-destruct: programmed to be overconfident, to keep on pushing for growth until limits are overstepped and risks accumulated to the breaking point. His offer of good news is that after the New Dark Ages, when civilization again rears its head, presumably with a much smaller population, we will have acquired the good sense to be less overreaching, less hubristic, a lot humbler about growth and our use of resources, and more determined to live in balance with the natural energy we receive from the sun and the heat, food, and water with which we can sustainably be provided.

I have just two comments about our current problems. First, that there is one particular pressure this time that seems particularly serious: aversion to bad news. The investment business has taught me – increasingly as the years have passed – that people, especially investors (and, I believe, Americans), prefer good news and wishful thinking to bad news; and that there are always vested interests to offer facile, optimistic alternatives to the bad news. The good news is obviously an easier sell. Good news in investing in particular is better for business; good news on resource limitation is better for the suppliers of resources; and good news on climate change – that it basically does not exist and is even a hoax – is better for energy companies, among the biggest and most profitable of all companies. Historians have pointed out the bias against the need for change: there are always clear beneficiaries of the current state of affairs but the benefits of a changed world in contrast will look vague and uncertain to the likely beneficiaries. That is always the case. What is less common, although not unique in history, is what we have today: the near complete control of government by the powerful beneficiaries of the current system.

The second point is that although I find Ophuls's argument well-reasoned and although I must acknowledge the strong possibility of a very negative outcome, I feel it is too pessimistic (which, sadly, is a rare occurrence for me on this topic). Yes, we are taking extreme risks with resource depletion and with the environment, especially concerning climate damage and ocean acidification. Yet I believe the case for the near certainty of our running off the cliff misses the existence of two extraordinarily lucky (and, one could argue, undeserved) gifts that were not available to any prior stressed civilization. They may arrive like the U.S. Cavalry, just in time to turn us away from the cliff edge. But at best, as Wellington is famously paraphrased as saying about the Battle of Waterloo, it will be a "damn closely run thing."[2] It will be the race of our lives.

Our Last Best Hopes: Declining Fertility and Improving Technology for Renewable Energy

Declining Fertility

The first of the two incredibly fortunate factors that might enable our current world to avoid at least partial collapse is declining fertility. Malthus correctly analyzed the main problem of our then history (in 1800): population had always kept up with food supply, leaving even successful societies only a few bad growing seasons away from starvation. He predicted that this would always be the case and he was wrong on two counts. The first is a short-term factor – only existing for 200 or 300 years and therefore irrelevant for the longer term of our species – and that is the increased ability to extract previously stored energy in the form of coal and oil. This hydrocarbon interlude will end either when that share of hydrocarbons that can be extracted economically is used up, or more likely when the tyranny of the second law of thermodynamics imposes its will: enough of the higher forms of convenient compact energy like coal and oil will have been converted into heat, waste, and especially carbon dioxide to ruin our climate in particular and our environment in general.

Malthus, however, completely missed declining fertility, a potentially very long-term and hence much more critical factor to the survival of our species. Neither he nor anyone else before 1960 even dreamed that we would voluntarily decide to have fewer children even as we became richer. In his day and until the early twentieth century, rich families routinely had eight or more children. Ironically, it has turned out that the same instincts that bring us the problems

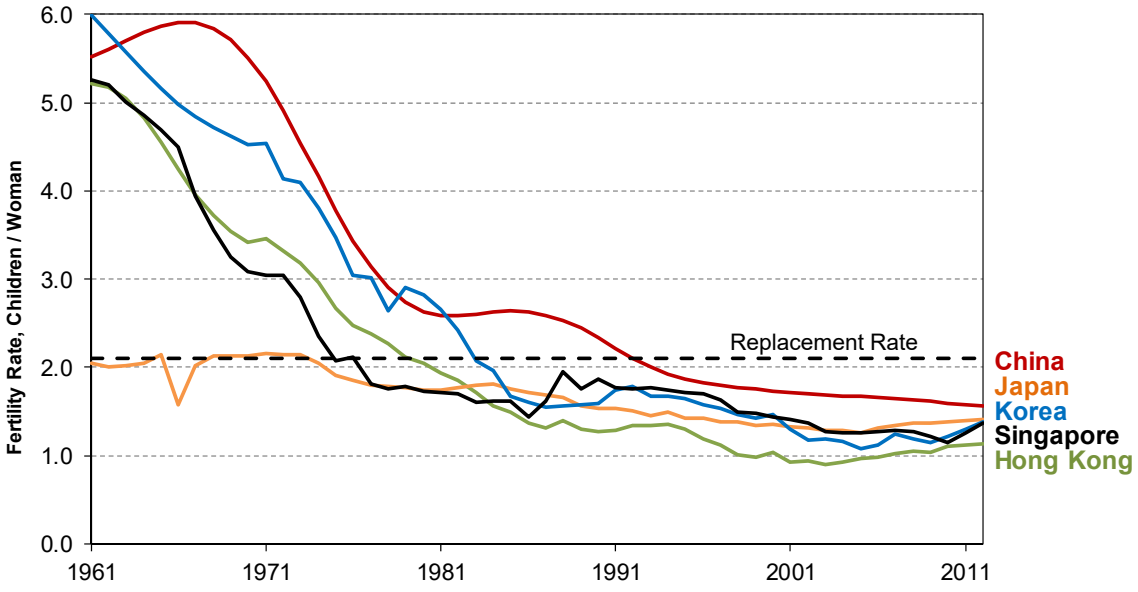
[2] The actual quote was, "It has been a damned nice thing – the nearest run thing you ever saw in your life." His is a nice use of the word "nice," which back then also had the meaning of "uncertainty."

of excessive consumption and unnecessarily rapid resource depletion have also brought us the attitude that children are inconvenient and desperately expensive. Improved medical services that further allowed populations to explode now allow the confidence to have smaller families. Increased farm technology lowers the significance of the labor from many children. The most obvious drivers of lower birth rates, though, are the improved education of women and advances in birth control methods. The net effect of these factors is a change so profound that just a hundred years ago it was not even guessed at, and indeed population growth and fertility continued to rise until about 1960 – just the other day.

The following exhibits show the remarkable and promising data. The dashed horizontal line at 2.1 in Exhibits 1 through 4 is the fertility level required to have a stable population in the modern world under normal conditions. Exhibit 1 shows the remarkable drop in fertility in the richer East Asian countries, including China, with almost a fifth of the world's population. Exhibit 2 shows the drop in the larger and wealthier countries to an average level just below replacement, with the very latest update for U.S. fertility in 2012 dropping below replacement. Exhibit 3 shows selected important and sometimes spectacularly unexpected examples. At the top of the unexpected list is Iran, which has dropped from a fertility rate of 7 – children per woman! – in 1960 to an almost unbelievable 1.6 today. Another

Exhibit 1

Falling Populations in Asia

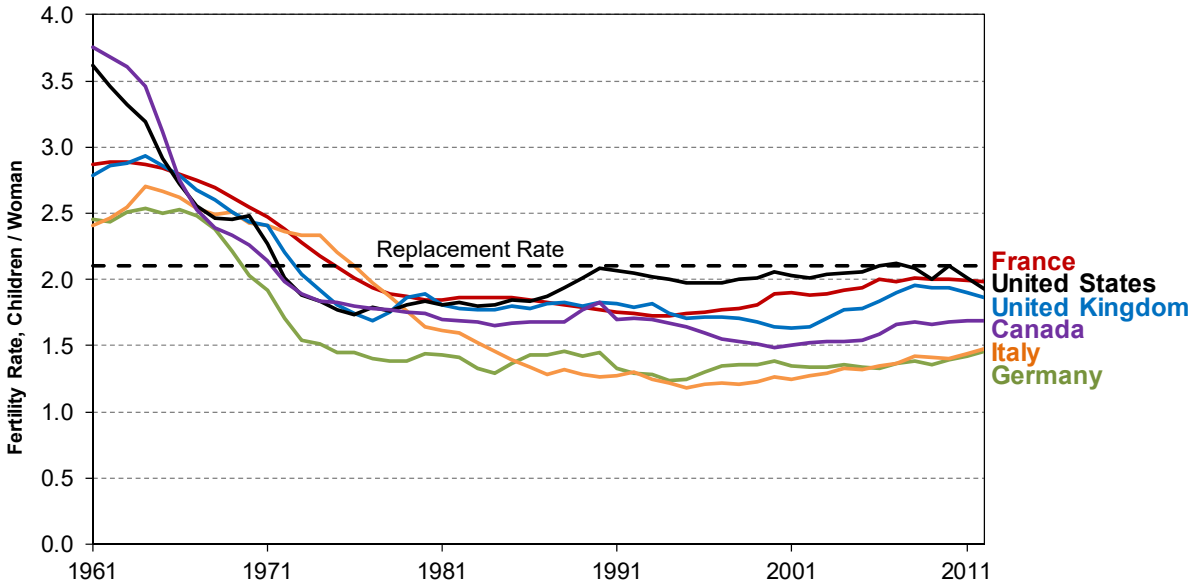


Source: World Bank As of 12/31/12

remarkable example of a large Islamic country is Bangladesh, which has also fallen from 7 in 1960 to 2.2. This is extraordinary given their extreme poverty. The particularly important India, with its 1.2 billion people, has fallen from 6 to 2.6. This is quite remarkable in absolute terms, but given the previous two examples and given India's pressure from overpopulation, it's almost a disappointment. Exhibit 4 shows the more serious disappointments. Yes, the rates have dropped in these countries, but their populations are still growing rapidly and most of them have intermittent food problems already. They are almost all in Africa. Unless they and the world are lucky and they improve (perhaps with appropriate help from rich countries), we are likely to end up looking to the students of long-term civilizations as if we have had two separate systems: one in Africa, with failed states, poverty and malnutrition, and rapid population growth, probably having been left increasingly to cope on their own; the second in the rest of the world, with substantial and still growing affluence and with fertility below the replacement rate, forming a single market for resources and global trade in general, and trading as if they comprised one gigantic old fashioned imperial economy.

Exhibit 2

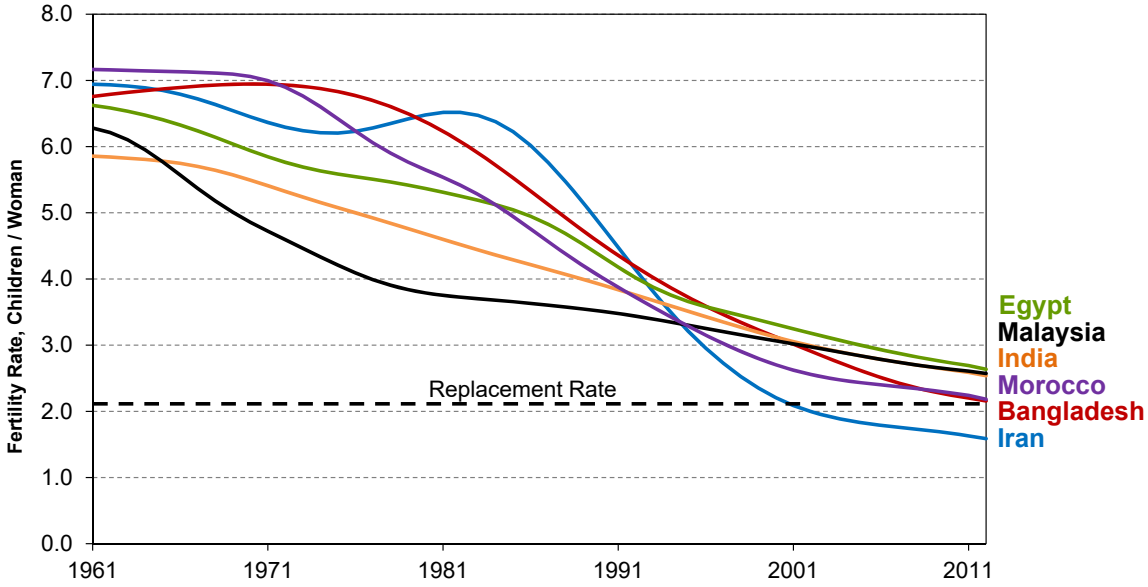
Low Birthrates in the "Western World"



Source: World Bank, Centers for Disease Control and Prevention As of 12/31/12

Exhibit 3

Important Declines in Emerging

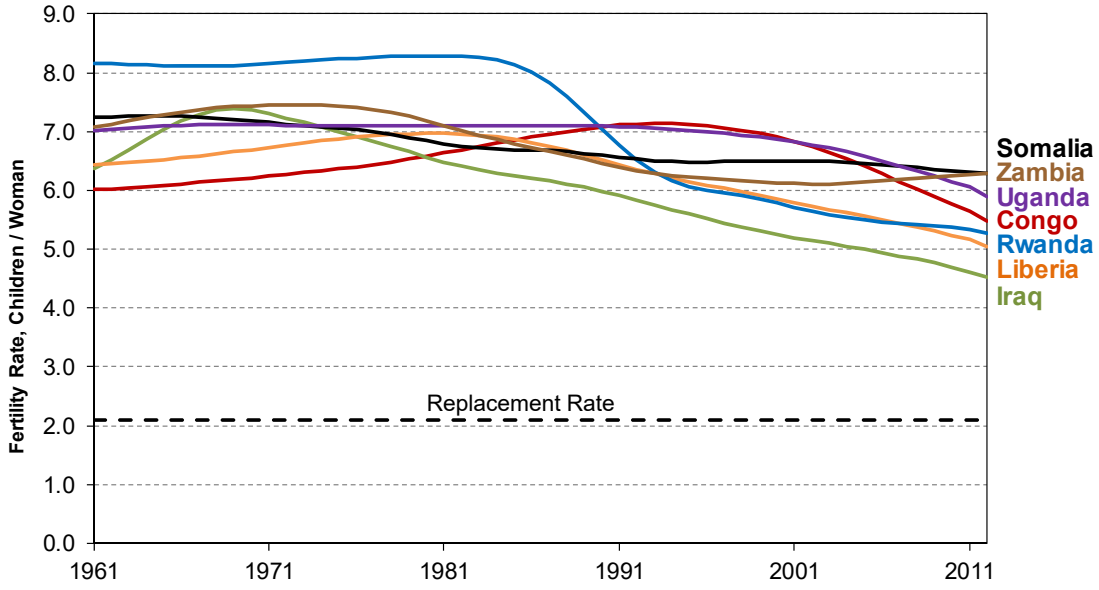


Source: World Bank As of 12/31/12

This remarkable decline in fertility is our last best hope, both from our civilization's point of view as well as for the well-being of all of the life on our planet. Exhibit 5 summarizes the past data and projects the more optimistic end of the U.N. data for future global population. The world's population is shown peaking around 2050 at just over 8 billion and then declining to near 6 billion by 2100. Ex-Africa, it reaches just under 6.5 billion in 2040 and declines

Exhibit 4

Holdouts / Failed States

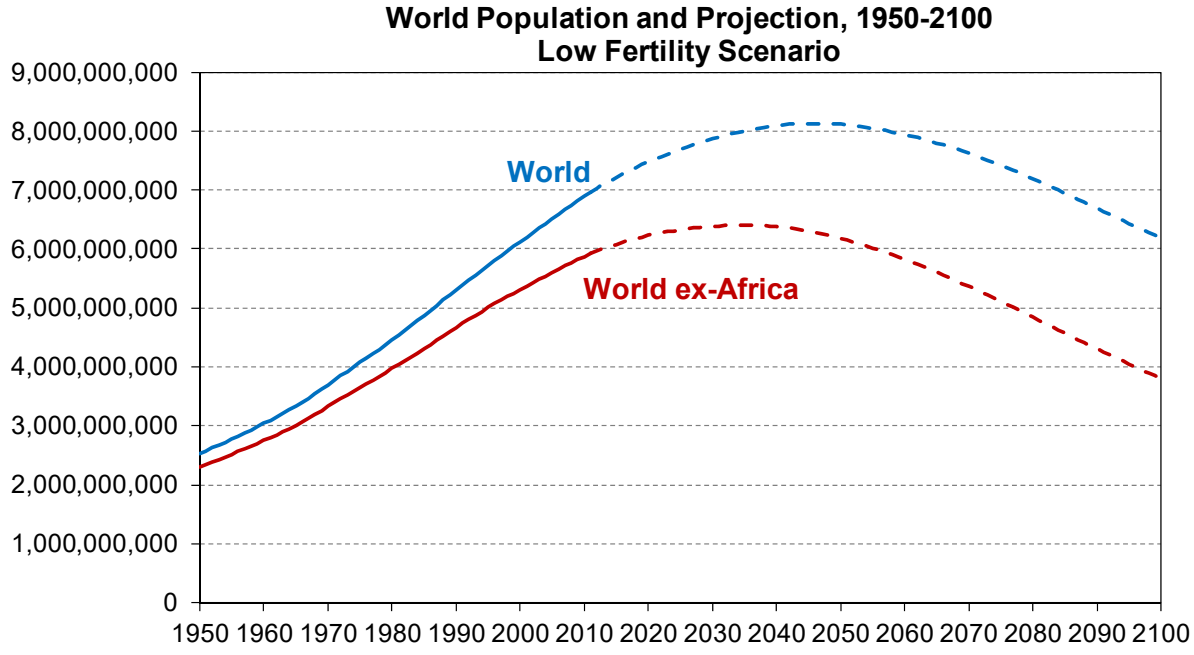


Source: World Bank, Centers for Disease Control and Prevention As of 12/31/12

to below 4 billion in 2100, back to where it was in about 1978. Africa is shown growing from about 250 million in 1950 to well over a billion today and, even under this relatively favorable outlook, continuing to expand to over 2.3 billion by 2100. The U.N.'s more pessimistic end of the range (not shown) has a continuing rise in population, but at

Exhibit 5

Important Declines in Emerging



Source: UN Department of Economic and Social Affairs As of 12/6/12

Future projections are not a guarantee and speak only as of the date they are made, and GMO assumes no duty to and does not undertake to update such projections. Future projections are subject to numerous assumptions, risks, and uncertainties, which change over time. Actual results may differ materially from those anticipated in the projections provided.

a slowing rate, to 11 billion and beyond. At that level the stresses on global food and on global law and order, especially in Africa, will almost certainly be too great and Ophuls's prediction will likely be correct. The lower population track, in contrast, holds out a strong hope of survival – that is, of maintaining a reasonably stable global civilization and continuing to improve the quality of the average life. The return, therefore, to helping encourage a lower population everywhere is incredibly high. Yet little is done at an international level and indeed the issue is treated like a hot potato even by usually well-meaning NGOs. But we can do it, and my guess is that we will indeed succeed on this front. In the meantime it would be encouraging if economists, *The Economist* (not to pick on them but I tend to hold them to higher standards than others), and economic discussions in general would look out a few more years and stop discussing lower population growth as if it were a dire economic threat rather than our last best hope. Of course, as growth rates drop rapidly and populations quickly age, there is an added burden to workers of carrying more non-workers for one generation as the changes flow through the system. Then things stabilize again. This cycle can be ameliorated enormously by having older people extend their contributions and by facilitating the full participation of women in all countries. The ruinous alternative is to have an ever-growing population run off the cliff collectively. The economics industry has indeed done a particularly inadequate job on long-term sustainability in a world of finite resources. It is a good time for them to wake up to the problems we face on this front. Fortunately, individual decisions on fertility might well get the job done anyway, without any help from a potentially less blinkered and longer-term economic theory.

Renewable Energy

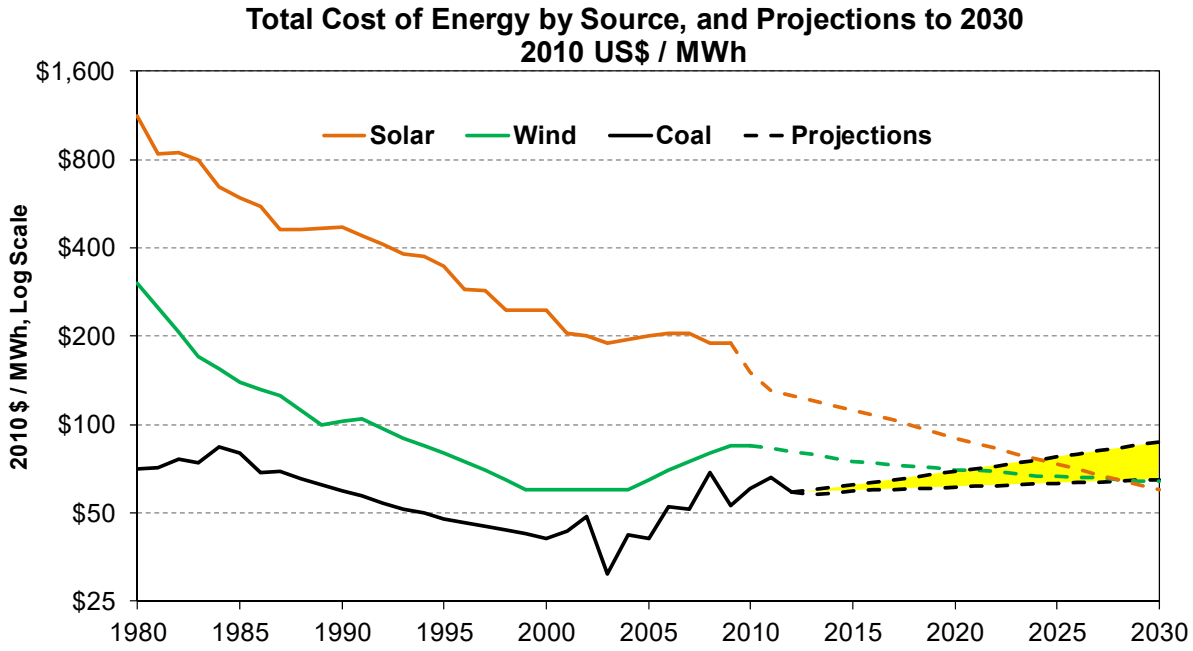
This brings us to the second remarkable gift, which involves a branch of the "cornucopian" optimism that I usually deplore: that the infinite human brain combined with technology will solve all problems. Yes, this is the same brain that brought us World War II, several thousand years of soil erosion, and the collapse of endless empires. An obvious generic weakness in this cornucopian argument is that it ignores our massive dependence on cheap energy. Trains and coal, cars and gas, and electricity and air conditioners and refrigerators in turn drove forward economic activity and the feeling of well-being (try being in Sydney on January 18, at 114.4°F, the hottest day in that seaside city's history, without air conditioning!), but each came with a cost – an increased wave of energy use, almost all of it from our irreplaceable stores of oil and coal. Yet now, finally, there is an example of a great technological leap that for the first time is accompanied by less energy use – the technologies of solar, wind power, and other alternatives as well as electric grid efficiencies and improved energy storage.

For once, all of the innovations, corporate start-ups, and risk taking – the best part of the capitalist system – work to decrease our use of depleting hydrocarbons and therefore to increase our chance of stabilizing our civilization before the cliff edge is reached. Exhibit 6 shows in orange the truly remarkable decline in the cost of electricity from photovoltaic cells. The only thing to compare it to is the Moore's Law decline in the price of semiconductors. That would indeed be a happy comparison, for perceived physical limits to semiconductor progress have been overcome time and time again. If the physical limits on photovoltaic efficiency, and hence its price, are similarly maneuvered in future decades, then the price of photovoltaic energy would guarantee us cheap and plentiful energy forever. Wind power may also be vital in less sunny zones, but there the cost reductions are, probably, mainly behind us. Exhibit 6 shows in green the early rapid declines in the costs of wind power mainly as improved technology allowed for increases in size and therefore efficiency. However, during the great leap in resource costs between 2002 and 2008, which I have been obsessing about for the last two years, the price of steel, cement, and aluminum from which wind towers are built (and all of which are incredibly energy-intensive), all rose from two to three times! Only the flat cost of human labor and improved turbines allowed for wind costs to rise by only 40% during this period. Our exhibit allows for only modest reductions in future wind costs, so that even by 2025 wind costs are estimated to be still higher than 2000, before the great surge in material prices. The remaining component of Exhibit 6 is the cost of coal-fired electricity. For future estimates we have made a range. The lower end represents a modest 1% a year increase in coal prices and the upper end 4% a year, which is still a little less than the 5% annual average price rise for coal of the last 10 years. As can be seen, by 2025 to 2030 both solar and wind power are likely to be cheaper than coal. All of these comparisons, of

course, are made without charging coal for "externalities" – those ills that the coal industry inflicts that we the people have to pay for: mountain tops ripped off and mountain streams polluted, acid rain, and particulate matter damaging

Exhibit 6

Renewable Energy Competitive Soon



Source: National Renewable Energy Laboratory, Greentech Media, McNerney et al., Global Financial Data, Bloomberg, GMO

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health. Even more serious in the long run, the CO_2 that is released by burning coal imposes the increasing costs of rising global temperatures: unstable weather for crops and rising costs of more extreme weather-related events. Coal is likely to be a hopeless choice for electricity generation in 20 years, as its price rises and those for alternatives fall, but fully costed for externalities it is an uneconomic choice today. Any potential investors today in a new coal-fired utility should ask some tough questions about "stranded assets" – cost-ineffective assets that will not have had the time to make a positive return on their investment before they will have become uncompetitive or illegal, caught between the falling costs of alternative energy and the rising costs of controlling for "externalities" – pollution and climate damage – that were once passed on as public costs but that will become steadily the responsibility of the emitter.

We have the time, technology, and money to completely replace nonrenewable energy in 30 to 50 years and, on average, in that time period such replacement will be economic (less so in the earlier years but by a wide margin later). As we do it, we will increasingly have much lower marginal costs, for what is often forgotten in these comparisons is that the high cost component in our two main alternatives, solar and wind, are up-front capital costs. Once constructed, the marginal costs of merely operating the wind and solar farms is far, far lower than the marginal costs of digging and shipping coal, even without those other health and environmental costs borne by the general public. You should be aware that when we calculate the costs of alternative energy projects, a high corporate discount rate is used to reflect the idea that to a corporation a dollar spent today to build a wind power project needs to be offset by a dollar and 10 or even 14 cents next year, or $8 or so in 18 years, to pay for the current loss of the use of money and to jump over the corporation's hurdle rate for attractive investments. The required investment return (hurdle rates) for alternative energy investments is often higher than for traditional corporate investments partly because of unnecessary uncertainties still surrounding these projects: erratic government policies, rapidly changing technologies resulting in most projects having new features, and general unfamiliarity to providers of capital.

But what of the social benefits of these alternative energy projects? Personal average wealth and income has been rising by only 1% to 3% a year for the last 30 years, not 10% or 14%! Solving our long-term energy problems may not only be the most critical economic problem, it may also, as I argue here, be one of two most critical inputs into our future viability as a civilization. A discount rate that would reflect this significance should obviously, in a reasonable world, be far less than the 10% or 14% return needed by a corporation for such projects. I could make a case for a zero social return hurdle in this extreme case, but let us merely settle for a lower-than-average corporate hurdle rate – say, 5%. At a 5% real return (which, by the way, compares to an average delivered 7% real return on all corporate capital in the past), these wind and solar projects would have a much lower levelized cost of energy (the cost that reflects both operating and capital costs) than they would have at higher corporate rates – up to 40% lower. At those lower capital costs typical wind power projects would have a lower "levelized cost" than a typical coal-fired plant and be far ahead in 10 years. Solar farms would still need 10 years at the current rate of progress in cost reductions to catch up with wind power (although roof-top solar is getting to retail rates as we speak). The point to remember is that once the capital is found and the project is built, a wind or solar farm delivers far cheaper energy than a coal-fired utility plant, at around one-third of the marginal cost of coal (about 1¢ per kilowatt hour at a minimum of 3¢ for coal).

The impressions the average businessman carries in his head tend to be a moving average of the last five years' information. Life is too busy to keep up with everything and usually five years is recent enough. But when there is a sudden shift in a year or two, average opinion is left sometimes far behind and that is exactly what has happened to solar energy and to a lesser extent to wind power. The current issue of *Prospect* magazine in England carries a story of an energy expert who invested three years ago in heavily subsidized home solar panels in the U.K. because doing so more or less guaranteed a 7.5% return (tax-free because the benefit comes in the form of lower bills), which for a low-risk investment was and is far better than anything else these days. You might suspect, the author argued, that the recent two-thirds drop in subsidies would end that game, but he points out that the installation costs of panels (adjusted for increased efficiency) have also dropped from £6,000 to £2,000 for a typical home in just over two years so that homeowners still receive a handsome return. You can just imagine how much easier it is to get a handsome return, without subsidy, at these new lower prices in areas where the sun actually shines – say, California, which receives almost twice the sun of London. (I'm stinging from a totally grey month in London.) At the other end of the spectrum, Duke Power was reported in Bloomberg as stating that the cost of solar panels to them had dropped by 75% in two years. These are truly remarkable shifts and now even modest steady progress from here will get the job done. Meanwhile in wind, the very latest large-scale wind farm in Australia was announced as having levelized costs lower than recent coal plants. All in a world where the cost of coal has doubled and oil quadrupled since 2000. This is not the same game that it was just three years ago.

Energy Storage

Energy storage is now the Holy Grail of environmental progress. The bad news is that progress in the past has been slow. The good news is that there are now scores, if not hundreds, of research teams working on this. Before wind and solar reach a large percentage of total electricity production, it is extremely likely in my opinion that some real cost progress will be made in storage (halving or so), especially at the retail level where a storage device, unlike a car battery, can be heavy, bulky, and relatively inefficient as long as it is cheap. Cheapness would deliver to the household electric market the potential for grid independence. However, let it be admitted that lack of expected progress in energy storage could materially slow down the rate at which alternative energy is adopted. It is therefore an area that particularly needs encouragement and good fortune.

Smart Grid

Over several decades, modernizing the grid to allow much wider and more efficient transfer would dramatically reduce storage needs. Reaching into homes and using temporary electric car battery and refrigerator adjustments, etc., (all by agreement and for a discount) would also reduce the problem. As back-up, natural gas electric generation

is the ideal technology with perhaps some use of bio mass and urban waste. Coal for electricity generation is just not necessary today in the U.S., and the last coal plants anywhere may be built in the next 20 years.

Chinese Cavalry to the Rescue

On this topic, I have high hopes of China setting a brilliant example. They are embarrassingly long capital, accused of wasting much of their 50% of GDP capital investments on subway stops in the middle of farm fields, empty cities, and redundant regional airports. We, in contrast, are embarrassingly short capital, with capital spending having fallen to 16% of GDP and federal debt owed to the public having accumulated to over 70% of GDP and currently increasing at 6% of GDP per year. China could smooth out their potentially dangerous transition from 50% capital spending to a more reasonable 35% over the next 20 years or so by managing a giant program of alternative energy, including the smartest-yet national grid and broad-based research into storage, and all sources of renewable energy, including fusion. (As with the U.S., natural gas from fracking would help in the transition.) Such a massive broad-based program would potentially give them global dominance in the most important industries of the future and would relieve them of their greatest single worry: energy security. It would also relieve them of what will surely become their greatest societal irritant: the incredible air pollution of their major cities, which must already be reducing life expectancy in those cities by several years, as well as substantially increasing health costs. Best of all for them, it would leave them as the low-cost energy player in global trade, and if that, added to their lower labor costs, rising educational standards, rapidly improving infrastructure, and capital deepening, does not put the fear of God into U.S. capitalists, then it should.

It would be a blessing in disguise for the developed world and the U.S. in particular if China announced a 25-year program of alternative energy (enough of these paltry five-year plans!) that embodied a Manhattan project level of commitment. Within just a handful of years of watching them execute this program, we would calculate the competitive consequences and would be forced defensively to emulate them. We would surely discover that we are in fact still wealthy and can afford worthy projects with long-term payoffs and that our perceived poverty is more about leadership and perceptions than it is about reality. The U.S. is, after all, richer than it has ever been and is still the richest large country in the world. I have made a part of this point before. I am repeating it because: a) it's very important; and b) the Chinese government has inexplicably failed to snatch up my idea. It would be a lay-up for them if they did. (Dear Chinese translator, a "lay-up" means "an easily achievable goal.") In a world lacking U.S. leadership in energy sustainability, a truly major Chinese effort might be the difference between collective global success and failure. In this case it would be the Chinese cavalry heading us off at the cliff edge, but I'll take any cavalry we can get.

(Postscript: recently, several leading Chinese cities recorded disastrous levels of pollution. On a scale where 30 is the barely safe limit, they hit over 300 several times. The Chinese government responded almost immediately, which was not a bad idea, because yearly reoccurrences of dangerous pollution will pretty soon guarantee that some smart but critical people will move out of these worst cities. Wouldn't you? They upped their current target [already very aggressive by U.S. standards] for installed solar generation capability in just three years by 65%! Astonishing by any standard and currently politically impossible outside China. This new target means that they will have the equivalent in solar power of seven[3] or so giant coal-fired plants, a very large absolute number anywhere except in China, where it is still dwarfed by coal plants. But, it is a down payment.)

[3] It is equivalent to seven or so coal plants in total electricity production, but in value terms it is more like 10 or more because the sun shines precisely at the time when high-value peak demand occurs.

Epilogue

The two favorable factors described, with luck and some improved effort and leadership, may buy us enough time to completely retune our agricultural system, for it will take many decades to change attitudes and build the infrastructure, training, and research to move to complete agricultural sustainability. That in turn would allow us time in a stable environment to address the problem that will no doubt take the longest time of all: addressing our failing supplies of metals. Yes, we are blessed with large supplies of aluminum and iron ore, although, like agriculture and civilization itself, their usefulness to us is completely dependent on the availability of cheap energy. More to the present point, affordable supplies of most other metals, some very useful, will run low this century and must be replaced by organic alternatives, which process will need all the time and research that success with the other factors might be able to deliver.

Suspended over this close horserace between destructive and regenerative forces are the wild cards of rising temperatures, slowly rising sea levels, ocean acidification, and, above all, destabilized weather for farming. Even if the cavalry arrives in time to prevent the main disaster – a rolling collapse of much of civilization – much damage is being done and will definitely continue to be done to the environment and biodiversity as global temperatures continue to rise. But with improved behavior, we may well buy enough time to save our own species and most of what we really value. In my opinion, all of the other factors in this mix are reasonably susceptible to data and analysis. The scary part of the climate issue is that by its nature there can be no precision on extent or timing and, consequently (as I have mentioned before), scientists, in their desire to avoid being seen to exaggerate, end up systematically underestimating the case.

The January 23 *New York Times* science section, for example, had an article on rising sea levels that said that the authors – scientists all – "share an emerging consensus that the increase in ocean level in this century will probably be on the order of three feet, perhaps as much as six feet," requiring many millions to evacuate. "But many scientists," they add "are plagued by a nagging fear… that their calculations will turn out to have been too conservative, and social stability will eventually be threatened." "At every point as our knowledge increases," Dr. Raymo,[4] the leader of the project, is quoted as saying, "we've always discovered that the climate system is more sensitive than we thought it could be, not less." [Emphasis added.] To be perhaps a little cruel, a statistician might suggest that after serial underestimations, expectations might be adjusted.

The bottom line is that if we put our minds to it we can overcome normal inertia and abnormally powerful vested interests that oppose necessary change. Our population is likely to start declining in a few decades, slowly but surely, and the fertility rate of 1.8% or less would allow global population to fall back more or less gracefully by 2200 to a probably sustainable level of 4 billion, particularly if we sensibly encourage its decline. Important progress in alternatives is certain. Other scientific progress, especially in computing power will also help. Whether we can move fast enough on these fronts and at the same time reduce the output of greenhouse gases to avoid going off the cliff is simply not knowable for certain, but every minute saved and improvement made, betters our odds. Let the race begin.

Correction: Natural Gas Forecast

I am bullish about the longer-term price of natural gas and in my personal account I am long the futures several years out. At five years out, the implied price is $4.50 mcf. However, in the Q&A section of a talk I gave recently I was quoted as saying that in five years the price "would have tripled." This implies a price, then, of $12. This is either a misquote or a misspeak. What I intended to say and have said before was that from the low last year the price would be likely to triple in 5 years: that is to about $6 or $7 mcf, far above the assumed $4.50 then, but far below the number in the quote.